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Commissioned and funded by the Gordon and Betty Moore Foundation

TRACING THE SUPPLY CHAIN

How blockchain can enable traceability in the food industry

The **Gordon and Betty Moore Foundation** is a private American foundation established by Intel co-founder Gordon Moore and his wife Betty Moore to create positive outcomes for future generations. The foundation fosters path-breaking scientific discovery, environmental conservation, patient care improvements, and preservation of the special character of the San Francisco Bay Area.

The Moore Foundation commissioned **Accenture**, a leading global professional services and consulting firm, to conduct a study exploring the feasibility of blockchain to enable end-to-end supply chain traceability in the food sector. The study looks at the opportunities and challenges of implementing this emerging technology, including business and environmental benefits and wider ecosystem and governance considerations.

The four commodities examined in the study—beef, soy, wild-caught tuna, and farmed shrimp—were selected because of their significant market size and environmental impact. The study seeks to demonstrate the art of the possible while bringing to light key trade-offs and considerations around implementing a blockchain solution.

Accenture and the Moore Foundation recognize the valuable insights of the members of the study's **Advisory Committee**, including representatives from the World Wildlife Fund, IBM, SAP, Microsoft, Republic Systems, and Synapse Nexus.

PROBLEM STATEMENT

Fjord Trends recently predicted that "making a difference will soon become a key point of differentiation" in the ethics economy. In fact, "the potential for ethics as a business metric is already the topic of some industry debate." [1]

In general, **companies do not know enough about the products that they buy and sell** to navigate the many complex challenges facing today's global supply chains (e.g., safe, sustainable, and ethical). Some companies are realizing the business value of traceability for efficiency, cost savings, and achieving product premiums in the market. However, they must first overcome the mistrust associated with validating claims of product identity and traceability. Companies should prepare for every action or inaction to be closely scrutinized.

More can be done to equip companies with real-time traceability of products within global food supply chains. Blockchain, a type of distributed ledger technology (DLT), has been increasingly gaining market traction in supply chains—for example, in proofing product provenance and implementing track-and-trace of products through the supply chain. While blockchain alone does not solve traceability, it can be a game-changer. When implemented effectively, it can connect and enable efficiency, transparency, and accountability among participating actors. **Better and more reliable data can help optimize business decisions and reach higher standards** for production, efficiency, and sustainability.

The market for blockchain technology is rapidly growing. In 2017, it was valued at around $754 million; by 2022, it is forecasted to be worth over $11.7 billion, growing exponentially at a compound annual growth rate (CAGR) of 73.2%.[2] In the provenance space, blockchain is expected to grow at a compound annual growth rate (CAGR) of 76.2%.[3]

Current and future state of food supply chain management

As indicated by a growing number of successful pilot projects, blockchain technology can improve the management of supply chain transactions by providing visibility and reliability of transaction information among participating parties. The certainty, transparency, tamper-evidence, and trust that blockchain provides can help to make transactional data easier to share and may provide a platform to promote more responsible practices across the supply chain participants through greater transparency, thus making it easier to hold parties accountable.

For example, BeefLedger has combined blockchain with Internet of Things (IoT), analytics, smart contracts, and digital tokens to track provenance, streamline payments, mitigate fraud risk, and provide transparency in sustainability in cattle ranching in Australia.[4]

Supply Chain Management

Due to rapid advancements in technology and the dynamic international business environment, supply chains are evolving into "supply chain networks," a more integrated form of supply chain that has arisen due to widespread technologies, such as the Internet.[5] Companies recognize that to succeed in the digital economy, they must manage the integration of business, technology, people, and processes not only within the enterprise but also across extended enterprises.[6]

Companies are increasingly looking toward adopting Supply Chain Management (SCM) systems that enable inter-enterprise cooperation and collaboration with suppliers, customers, and business partners.[7] Although there are potential benefits for achieving competitive advantage, companies also face significant challenges in digitizing their supply chains such as:

- Coordinating process and digital transformation across multiple, disbursed, and often disconnected supply chain actors.
- Lack of connectivity, particularly with upstream suppliers.
- Onerous and costly data reconciliation processes.
- Ineffective solutions for handling large amounts of disparate and potentially inconsistent data.
- Making relevant parts of the SCM system and the data it captures available to be shared between different actors to foster cooperation and collaboration across the entire value chain in a secure and trusted way.

Why blockchain now?

While other technology options exist to help manage supply chains, blockchain provides another arrow in the quiver, one that can bring together different parties that have not directly established trusted relationships with one another through the transparency it provides and its tamper-evident nature. Blockchain stores every transaction or exchange of data that occurs in the network, potentially reducing the need for third parties and/or intermediaries by providing a means by which all parties in the network may share access to the same data, including what is added to the data, by whom, chronologically. Data cannot be removed. By enabling each party to see the same data, in near real time, and assure that 'you see what I see' from a data perspective, blockchain can help eliminate complex and costly data reconciliation required by most systems in the world today.

Blockchain alone does not solve the human challenges at hand or the need for digital transformation, but it can be a powerful prompt for new ways of working, enabling greater accountability and trust when implemented effectively. Additional value drivers for blockchain may include:

- **Efficiency gains** – Substantial efficiency gains expected in reducing manual processes for cross- party data validation and reconciliation and reducing repetition.
- **Brand enhancement** – Improved trust in product provenance and secure consumer confidence for quality, societal, and environmental impacts.
- **Revenue growth** – Market penetration and new product/markets development.
- **Risk reduction** – Reduced risk of counterfeit products and mitigated risk from lower-quality components.
- **Cost savings** – Improved financing and credit rates due to greater transparency and certainty of movements of products and savings through streamlined operations.
- **Innovation drive** – Leverage innovation to increase efficiency and change the ways of working.

When considering whether blockchain is feasible and appropriate for a specified use case, various costs and trade-offs should be considered. Blockchain is not a silver bullet and some supply chains may be better served through other existing technologies and solutions. Further, different stages of the supply chain might be more suitable and feasible for leveraging blockchain than others. A few key trade-off considerations include:

- Value for each actor
- Availability of supporting infrastructure, i.e., tools, and enabling technology
- Level of digital maturity of various actors
- Level of connectivity
- Level of data quality and standardization
- Incentive(s) for different actors
- Level of collaboration/mistrust between partners
- Investment required (cost to set up, digital transformation, and technology operations)

Further detail is provided throughout the report on the benefits and trade-offs for the four selected commodities.

VALUE LEVERS
SPECIFIC TO COMMERCIAL FOOD SUPPLY CHAIN COMPANIES

While many industries, organizations, and companies are experimenting with blockchain and its applicability to their businesses, many are also beginning to explore the collaborative potential for enhancing the workflows in their supply chains.

They recognize that existing and new ways of operating enabled by blockchain could one day become commonplace in supply chain ecosystems, allowing for increased transparency of products, transactional efficiency, reduced costs, and fewer redundancies. Below is a list of three main supply chain management challenges that businesses seek to address:

CHALLENGE 1
Coordinating across multiple, disbursed and often disconnected supply chain actors

Complex, global supply chains, such as the ones in this report, involve many independent actors—producers, brokers, transporters, processors, wholesalers, retailers, and consumers—who may not trust each other. This can greatly limit the level of collaboration. For example, these actors may be hesitant to share data and/or invest in a direct relationship or intermediaries that would allow for sending, validating, and reconciling data between different parties. Business models that provide flexibility in coordinating across these many actors are required.

CHALLENGE 2
Onerous and costly data reconciliation processes

As businesses expand into multiple facilities and countries, it can be difficult to keep track of inventory and manage the numerous data and regulatory requirements. Supply chain management, in general, can result in a large amount of duplicative data and huge efforts in the tracking and reconciliation of data for a single transaction, from start to finish, including capturing any exceptions. Accenture refers to this as a "hall of mirrors"[8] effect, where many parties end up with copies of the same documentation (e.g., certifications, transport orders, bills of lading, pallets, loads, etc.), and there is risk of the data becoming out of sync.

It then becomes difficult to identify original versions or decipher the accuracy of the information held. In many cases, these reconciliation processes are still manual and paper-based, and errors and data duplication lead to high reconciliation costs. In the case of the four commodities in this study, there are multiple actors who use various facilities (for example, pre- and post-processing), adding to the complexity of the supply chains and tracking. For example, beef is a highly processed commodity that changes product identity through the process and chain of custody. This complexity raises the demands for reliable data that can be trusted between parties.

CHALLENGE 3
Lack of product traceability

According to a 2011 Grocery Manufacturers Association report, most companies that go through a Class One recall, when the public health impact has the potential to be most severe, can expect a financial impact of $10 million or more. Nearly one in four companies report a financial impact in excess of $30 million for a single recall.[9] A major challenge in traceability is product information ambiguity, resulting from logging vague and uncertain product characteristics that are hard to trace. This may be due to poor and predominantly manual record keeping, supply chain complexity, and identification lag time. Particularly challenging is when products are blended or comingled or when a raw material is used to create a semi-finished or finished food product. Traceability problems can also arise when products change identifiers or possession, are repackaged or cross borders when both naming and labeling methods vary. In the case of the four commodities in this study, we have observed several bottlenecks that make end-to-end traceability more challenging. For example, the limited use of digital records, lack of standardization, and costly reconciliation appear in all four commodities.

Although relatively new, blockchain is already generating excitement among some companies in these industries. That's because it offers many benefits that are valuable to diverse actors in a supply chain:

VALUE 1
Transparency and auditability

The lack of consistent data and digital capabilities makes sharing information across the supply chain difficult. Blockchain can help promote transparency and help streamline the process of sharing information. Because each actor can upload information and data about their products, this transparency also improves accountability and trust. Blockchain can also show near real-time updates about the product. Depending upon the governance and policies of the network, trading partners can see where the product is, who made it, how it is made, and when it is expected to be delivered, using a single platform.

The enhanced communication through a visibly streamlined process has shorter lead times, reduced redundancy, and fewer delays. A blockchain-based solution for information sharing can provide more direct visibility on whether contracts and agreements are adhered to and properly documented. Since each transaction is recorded in sequence, blockchain provides a permanent audit trail that can verify a product's authenticity and trace it through its chain of custody. Much of the complexity, costs, and inefficiencies of current processes could be reduced through blockchain-enabled systems, effectively "closing the hall of mirrors."[10]

VALUE 2
Product traceability

At the time of this study, there was limited widespread adoption of traceability software within the four commodity supply chains covered. That said, companies are increasingly investing in automated food safety software that allows them to see where products are and where they came from within the supply chain. Automated food safety software also helps with U.S. Food and Drug Administration (FDA) compliance requirements in the event of a recall, allowing them to more quickly access data and detect a problem, including lot codes, production and expiration dates, and product order numbers.

Blockchain can be a significant game-changer here by enabling interoperability between these various traceability solutions without the need to replace the applications or moving onto a single solution for all entities on the supply chain. This is highly valuable when there are multiple entities on a supply chain that do not need or want to directly integrate with each other or be impacted by another entity's technology and/or business decisions. Blockchain enables data sharing without the need to change the systems that each entity has and thus enabling greater traceability of products across multiple partners, locations, and facilities. Each stakeholder can view the same data on a product's lifecycle.

VALUE 3
Streamlined operations and purchase process automation

Because of predominantly paper-based records and manual processes, tracing products—particularly during a recall—and reconciling accounts and transactions can be costly and time-consuming. With blockchain, key information is stored and available in near real-time to the users that need it. Applications that sit on top of a blockchain platform move data to the blockchain, either through human entry or an automated process or technology (for example, through an automatic sensor measuring temperature in a transportation truck). Multiple entities can then view the information they need in one location instead of having to communicate with their suppliers or purchasers.

A smart contract is a component of a blockchain-based system that can automatically enforce participant-agreed rules and process steps that can facilitate, verify, and execute the terms of an agreement between counterparties without the need for a human intermediary. In traditional database terms, smart contracts are like "stored procedures," but in this case represent an agreement among multiple entities, such as with service payment or shipment authorization. Since blockchain is distributed and scalable, it can reach and support global partnerships and streamline communications.

VALUE 4
Security and trust

In tuna, shrimp, and beef supply chains, there have been significant issues with product fraud and inaccurate labeling, and it can be difficult to detect fraudulent actors and/or transactions and hold them accountable. Though the initial data accuracy is still dependent on the person or the device entering the data correctly into system, leveraging blockchain means that it is easier to identify an issue after the initial data entry. Blockchain operates by recording and storing every transaction chronologically across the network in a cryptographically linked block structure that is replicated across network participants. Through its inherent structure, blockchain can enable trust in the source of data coming from multiple data streams, providing confidence and visibility that the data has not been tampered with or altered inappropriately.

VALUE 5
Contract management and supplier due diligence

By automating certain types of contracts, blockchain can simplify and expedite contract management for modern supply chains by reducing the need for intermediaries and allowing organizations to connect with each other directly. It also unlocks the potential to more efficiently share data, such as inventories, which could enhance a company's ability to manage multiple suppliers and unique contracts, reducing their dependency on single entities and lowering overall risk. Additionally, blockchain's potential for shared inventories and automated purchase orders could accelerate product movements through the supply chain, reducing risks of perishability and improving the ability to more efficiently match consumer demand. And finally, performance data collected on a blockchain can help reduce risk and allow suppliers to demonstrate their performance to potential clients.

VALUE 6
Trade finance, insurance premiums and liquidity

Despite their importance in the world economy, small and medium-sized enterprises (SMEs) in food production, such as beef, soy, wild-caught tuna, and farmed shrimp are underserved by the banking sector and often face problems accessing credit when and where they need it due to lack of trust and availability of information. There is not much scope for negotiations when securing finance because the rate of borrowing for the SME (supplier) or their cost of working capital is dependent on the corporate partner's (buyer's) bank.[11] Typically, the lack of transparency inherent in these transactions results in uncertainty, or a lack of trust between parties, and thus buyers are unable to improve cash flows for their upstream supply chain, making it very difficult to finance the buyer's tier 2 and tier 3 suppliers (i.e., the supplier's suppliers).

To address these issues in a cost-effective way, organizations are investigating the use of blockchain technology for supply chain financing.[12] Blockchain enables a much higher level of certainty in where the data comes from. This improved confidence and assurance in information can in turn help the farmers and other actors in the supply chain to provide great liquidity, better terms, and improved access to insurance, financing, and other capabilities. For example, insurance can be critical to smallholder farmers, yet without strong proof of ownership, or volumes, insurance premiums could be higher (or payouts lower), which can impact the farmer's bottom line.

Additionally, blockchain improves efficiency and can reduce processing times, eliminate the use of paper, and save money while also ensuring transparency, security, and trust. It opens an online marketplace for the buyer, supplier, and financiers, facilitates trade directly between these parties and eliminates the need for intermediaries.[13]

VALUE 7
New channel of customer engagement

By enabling access to the same set of data, blockchain can provide greater transparency to multiple stakeholders in the supply chain. For the smallholder farmer or producer, it can provide greater visibility into demand upstream for access to better prices, better production control (to avoid under/overproduction), or potentially direct income. Suppliers can use this information to view items in the production process to build a better delivery time for their store. This gain can improve communication and boost customer satisfaction and retailers may choose to engage customers by providing access to some information on the blockchain. For the consumer, this can provide increased visibility into product origin, producer, quality, and the like, which in turn can build loyalty and contributes to a stronger business relationship. This could be facilitated, for example, by a mobile application that allows a consumer to scan a product or QR code to view such information.

VALUE 8
New business models and sustainable product differentiation

Some of the most significant technological advances have led to a complete reinvention of an industry and creation of new ones. The disruptive effect on current business and operating models that blockchain can have should not be ignored.

If products could be more easily identified and tracked more effectively, providing greater transparency in how they are produced, then actors are more incentivized to improve their processes. Blockchain could also potentially automate buying, changing the functions of intermediaries handling transactions in much of our global trade. Just as the Internet and e-commerce allowed customers to bypass physical brick and mortar stores, blockchain could potentially allow producers to be connected directly to consumers and create different marketplaces.

Blockchain solutions could also change the terms of insurance policies currently required in transactions and global shipping as well as how liability and indemnification are identified in supply chain management.

Transparent, real-time insights into product movements could create a more responsible and collaborative approach to global trade, reducing costs and time, and increasing efficiencies.

For instance, producers, who often have a limited view of global markets and demand, can benefit from trusted data insights into customer demand; they can leverage the data to reduce risk of overproduction and waste and improve profitability.

There has been significant research and evidence pointing to a large market for sustainable goods and a strong opportunity for companies to demonstrate the sustainability of their products. Indeed, in a recent study, Unilever determined that the opportunity is worth over $1 trillion for brands that can effectively market and communicate their sustainability to the market.[14] As Unilever's chief marketing and communications officer states, "This research confirms that sustainability isn't a nice-to-have for businesses. In fact, it has become an imperative."[15] Blockchain can allow, for instance, consumers to more directly drive the demand for ethically and sustainably sourced products by linking the consumer with the producer.

INTRODUCTION TO BLOCKCHAIN

At its core, blockchain is a new type of data system that maintains and records data in a way that allows multiple stakeholders to confidently share access to the same data and information.

A blockchain is a type of distributed ledger technology (DLT), meaning it is a data ledger that is shared by multiple entities operating on a distributed network.

This technology operates by recording and storing every transaction across the network in a cryptographically linked block structure that is replicated across network participants. Each block has a hash, which is the output of an algorithm that turns the contents of the block into a random mix of letters and numbers. By mathematically validating that the hashes match the expected values, users can trust that the data has not been tampered with. Relevant actors or organizations participating in the distributed network can serve as “nodes” to participate in consensus, a process that keeps each blockchain node in sync and handles the addition of new blocks. There are different mechanisms that could be used to establish consensus that have trade-offs between confidentiality, throughput, and security, and vary depending on the implementation and use case.

Public blockchains use complex algorithms to reach consensus among network participants but may not be suitable for companies in many cases, as they have limited privacy protection compared with private blockchains. Private blockchains use access control layers to specify the network participants and commonly use high-throughput consensus mechanisms.

Depending on the type of blockchain platform being used, blockchains can be designed to provide different levels of access to the data on the blockchain (“on-chain” data). This means it can provide increased transparency to the data, while upholding privacy where needed.
For instance, a blockchain could enable patients to control their own health data and choose who can access their health data.

To protect sensitive information, it is recommended to store this information “off-chain”: rather than being stored and replicated across nodes within the blockchain structure (“on-chain”), data would be stored elsewhere, separate from the blockchain.

Additionally, most blockchain platforms cannot efficiently store large volumes of data on-chain. Only the minimum data elements needed to enable a transaction should be stored on-chain to comply with storage limitations and privacy needs. Information that could be stored on the blockchain might include:

- Transaction metadata (such as time stamps, actor/user IDs, transaction types, etc.).
- Pointers to the actual data that is stored off-chain (e.g., confidential compliant database), which would only be accessible by authorized users.
- Access Control List, listing actors who have been provided access to read or update data that resides at the pointer.

Using blockchain in this way establishes trust in the validity of the data and improves the ability to share the data across silos while keeping sensitive data protected.

But in terms of its potential, blockchain is more than just a technology. It is a critical enabler of innovation as it acts as a catalyst for changing the way that existing trading partners in a supply chain work together. Blockchain makes it possible for a system of independent actors—producers, brokers, transporters, processors, wholesalers, retailers, and consumers—to share the same data between the different actors without the actors having to directly interact and build a direct relationship with one another. In doing so, it offers the potential to disrupt and transform existing business models: instead of the various processes associated with sending, validating, and reconciling data among different parties, blockchain can be used to reliably share information among multiple selected parties while still allowing parties the ability to control who gets to see what data. Blockchain introduces a means to share data across multiple, possibly mistrustful, parties without the necessity for an intermediary, reducing the need to revalidate and reconciliate data.

The decentralization that blockchain provides reduces the risk of data loss or corruption from single-points-of-failure and data-fragmentation disparities. The tamper-evident nature of blockchain means that, should an actor attempt to change data on the blockchain, network participants would be immediately aware of the change upon inspection of the chain—thereby making it very difficult to introduce non-accepted or malicious data.

Blockchain technology can offer many benefits to disparate organizations that have an inherent lack of trust between one another, but that would benefit from sharing a common set of data to facilitate business objectives. The distributed nature of blockchain solutions enables businesses to see and trust the data they are sharing, with confidence that it has not been tampered with or altered inappropriately. All of this is made possible by the combination of cryptographic concepts that form the backbone for blockchain and provide immutability and auditability to the data records.

Figure 1: Four key features

Provenance

We know where data came from and can trace its complete history

Tamper Evidence

We know if someone has tried to change it

Control

We can control what someone can see and do at a data element level

Security

We can encrypt and segregate data at a data element level

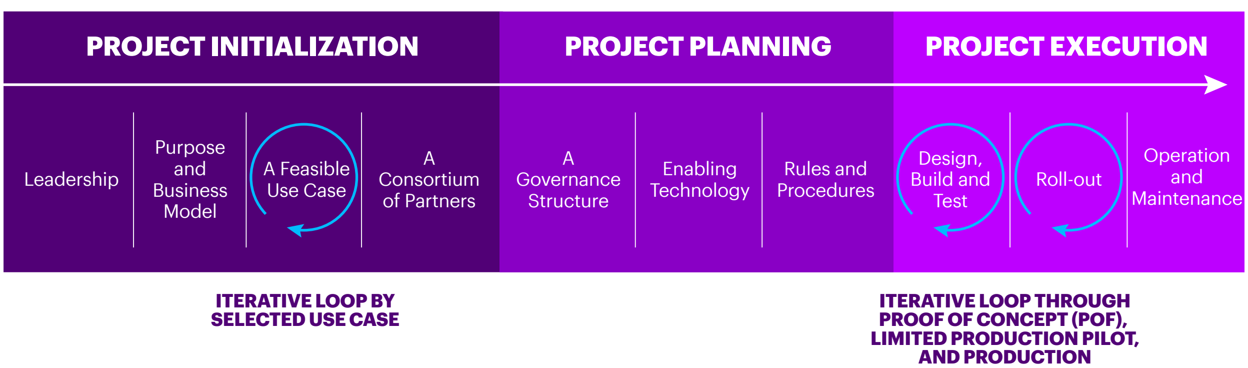
BLOCKCHAIN ADOPTION

The successful application and adoption of blockchain agriculture supply chain traceability must provide value and benefits to each actor in the supply chain.

The value that such traceability brings to each of the actors will be different and needs to align to each actor's specific part of the supply chain to increase incentives, promoting greater traceability. A blockchain traceability solution requires robust governance, strong coordination, and a comprehensive technical and functional strategy that works for a broad set of actors in the supply chain and a strong supporting ecosystem.

This section identifies the key components of implementing a blockchain traceability solution:

Figure 2: Blockchain project implementation process



Source: Accenture

1. Leadership

Every project has a certain culture that is created by its members and cultivated by the project's leader(s). The human or social problems are the most significant obstacles to success[16] and cannot be resolved by technology. They require human leadership striving for innovation and improvements of existing processes through the following activities:

- Identify the business or societal need(s) and focus on the value that needs to be delivered.
- Assess and determine if blockchain would add value to addressing the concerns.
- If blockchain could add value, identify the right consortium partners. Provide early-stage leadership and vision for innovation and collaboration.
- Allocate initial human and financial resources to catalyze the project.
- Convene relevant supply chain actors and technology partners.
- Facilitate collaboration, consortium-building activities, and committees or working groups.

2. Purpose and Business Model

A blockchain solution typically serves the following purposes:

- To better address a business's supply chain management objectives, including cost, efficiency, transparency, accountability, traceability, trackability, quality, speed, dependability, risk reduction, sustainability, and flexibility.
- To enable a new business model or differentiated product.
- To meet customer demand or market trends, such as provenance, ethical consumerism, or greater collaboration.
- To address a significant gap or problem in the supply chain due to lack of transparency or data-sharing issues.

3. A Feasible and Valuable Use Case

Blockchain presents a tremendous opportunity to transform the food sector and enable environmental protection. However, it may not be appropriate for all commodities, supply chains, and use cases. It is important to assess the feasibility of each use case to determine suitable candidates. The minimum criteria for a valuable and achievable blockchain system should include:

Market feasibility and value:
The appropriate demand and market conditions are in place to enable participants in the market to be interested and beneficial to participate. The solution must provide demonstrable business value and incentives for each participant in the blockchain ecosystem.

Technical feasibility and value:
The technology is a good fit for the industry and its actors' needs; these needs should be addressed directly through the key benefits that blockchain technology specifically brings, including its ability to allow multiple parties access to the same data.

Operational feasibility and value: There is sufficient capacity and coordination to enable adoption. This would include a practical and manageable governance model for effective collaboration, as well as capabilities, processes, training, and the like, to put the solution into practice, and sustain and scale the solution.

Financial feasibility and value: Introducing blockchain is financially feasible because the required capital is available to the actors who need it, and they can reasonably expect a return on investment either through revenue increase or cost savings.

4. A Consortium of Partners

Blockchain allows for the sharing of data across value chain actors who may currently lack trust. In order to enable parties to collaborate and work together, including potentially direct competitors, to achieve business value across actors, technology partners, and a consortium of industry, regulatory, and nonprofit stakeholders should be brought together to agree on ways of working, governance, ownership of Intellectual Property (IP), and liability. Value needs to be front and center of the consortium as members determine their operating structure, solution capabilities, technology solution, and operations to meet the needs of all involved. Connecting these partners in a consortium requires significant coordination, effort, and investment.

5. A Governance Structure

To build a successful consortium commitment from relevant parties, the development and operations of an appropriate governance structure to drive the intended values and desired behavior from all participants is required. Strong leadership, commitment, and change management are necessary. Participating organizations will have to adopt new ways of working in an ecosystem to realize the full benefits of the ability to share data and processes. Rather than the traditional way of each entity owning their own system and relying on data within their own perimeter, organizations would need to change how they approach ownership of data, systems, and their supply chain management operations.

6. Enabling Technology

It is at the base of the pyramid where the lack of transparency produces several issues—from availability and reliability of information on the product and farming practices, to labor management, to payments, and each has significant impact further along the supply chain. While blockchain alone cannot solve the existing manual processes, the digital divide, the lack of access to connectivity, nor the quality of the initial set of data input, it can help with transparency and ability to share data across different parties in a consistent and integral manner. To reap the benefits of blockchain in agriculture and aquaculture, a key dependency is digital transformation of the industry, especially for base-of-the-pyramid producers.
As such, other enabling technologies and capabilities, which together make up the larger ecosystem, must be considered.

Several existing technologies are expected to interface with blockchain solutions:

- Enterprise resource management (ERP) systems
- Electronic ordering and payment systems
- Invoicing systems
- Logistics systems
- Order management systems
- Traceability systems

Additional capabilities will be needed specifically for base-of-the-pyramid producers in emerging countries, including access to digital technology and devices to help close the digital divide, better access to connectivity, increased availability of mobile devices, better basic infrastructure, IoT sensors (temperature, grading, safety, etc.), RFID systems, barcodes and scanners, and better access and link to connect farmers to consumers.

7. Data Accuracy, Collection, and Entry

While blockchain enables greater transparency, it cannot ensure correct data entry. Traditional methods of data collection, from paper to simple spreadsheets, can still be used and data can be manually entered into applications that interface with a given blockchain supply chain network for tracking information. There are additional commonly used controls and methods that reduce the risk of incorrect data entry for applications that can be deployed to increase the level of assurance for accurate data added to the blockchain. Examples include data validation tools and reentry of data to check for a match.

As the industry demands greater automation and accuracy of data, the industry is trending toward greater adoption with IoT and automated data collection, with, for example:

- Product tagging (RFID, NFC-embedded ID chips)
- Digital quality assurance checklists
- A GPS-enabled smart logbook
- IoT devices—scanners, sensors, cameras, etc.
- Smart packaging and digitized labeling
- Tamper-evident seals or security stickers
- Identity management of devices, commodities, and users

8. Rules and Procedures

Rules and procedures need to be established between stakeholders to determine what data should be on-chain, what types of data should be added, who gets to see what data, and especially how data additions will be accepted (consensus). When a transaction is added to the blockchain, a consensus mechanism among the stakeholders determines whether that data is valid.

Buying and selling transactions follow rules that parties agree on beforehand through a legally binding contract. Blockchain can solve certain problems inherent in the traditional value exchange process by using cryptography and distributed computing and storage technologies to provide trading parties with a means to share a trusted representation of their transactions and assets.[17]

Additionally, required data should be standardized across supply chain actors. Data standardization may mean adopting an existing, well-known standard or creating one for the consortium. It is not necessary to agree on every piece of data. A good starting point would be to determine a small set of data attributes that are required by all parties in the ecosystem and focus on the definition of a small set of common data. Not all data will need to be shared.

9. A Strong Supporting Ecosystem and Incentives for Change

Blockchain has the potential to unlock significant value for the different entities in the supply chain if it is designed, built, and operated with the right incentives and ecosystem in mind. For users and organizations to adopt the technology and form new ways of working, such as a consortium, there must be sufficient incentives for change; these incentives could include financial, reputational, and operational gains. The blockchain supply chain capability and operating model needs to deliver value to each entity in the network for it to be sustainable. Additionally, user experience and utility for the user need to be improvements on how things operate today.

A critical challenge to addressing unsustainable practices is one of incentives and disincentives for good and bad behaviors within the supply chain.

Investing for the future

Investments in traceability, including traceability technology, have been limited to larger operations, particularly those that are either vertically integrated or have less complex supply chain systems. Aside from adoption, value delivery and utility, like any digital transformation or adoption of traceability technology, the long-term success of blockchain solutions and ecosystems across geographies is also subject to socio-economic and regulatory factors, especially in regions experiencing instability and/or lacking sophisticated systems and frameworks.

It is important to address the key drivers for investment in a blockchain-based traceability system:

- A clear and compelling value proposition for traceability and sustainable production.
- Practical and comprehensive standards for traceability and sustainable production.
- Cost-effective enabling processes and technologies.
- Appropriate levels of communication and coordination across the supply chain.
- Appropriate incentives for participants to join the network.

INTRODUCTION TO USE CASES

This report assesses the feasibility of blockchain to enable end-to-end supply chain traceability in the food sector, specifically across four commodities: beef, soy, wild-caught tuna, and farmed shrimp. These commodities were selected because of their significant market size, health, and safety as well as their social and environmental impact.

Use cases were also designed to meet the objectives shown in Figure 3:

Figure 3: Use case objectives

A clear, consistent objective of the blockchain

A clear start and end point

A consistent definition of essential data and why it is required

Sufficient information available about the supply chain and the specific use case

Sufficient integration and consistency within the supply chain

Following a detailed supply chain mapping for each food commodity, obtained through secondary research and primary interviews, the team completed an analysis and evaluation of each use case against four feasibility criteria (technical, operational, market, and financial). The findings of this report point to an indicative ranking of the feasibility of the four food commodities in terms of blockchain feasibility. This report finds that, in this order, Indonesian wild-caught fresh/frozen tuna, Thai farmed shrimp, Brazilian soy, and processed Brazilian beef rank most to least feasible for a blockchain traceability solution. Additional context is provided in Figure 4.

Figure 4: High-level feasibility findings

AREAS OF COMPLEXITY

Technical
Technical complexity of establishing and maintaining product identity and traceability data.

Operational
Operational and organizational complexity of building core capabilities among actors and processes to enable traceability.

Market
Complexity of introducing a traceability technology within the market and regulatory context.

Financial
Complexity of financing traceability technology and infrastructure.

FINDINGS

Most Feasible

- Indonesian wild caught, fresh/frozen tuna
- Thai farmed shrimp
- Brazilian Soy
- Brazilian Beef (Processed)

Least Feasible

Source: Accenture Analysis

Profile of the four use cases

INDONESIAN TUNA

Indonesia's tuna landings are the largest in the world, contributing 17% of the world's tuna supply and 27% of U.S. fresh and frozen tuna; however, unauthorized tuna fishing in Indonesia is leading to the overexploitation of seafood resources in surrounding waters. Indonesia is the top exporter of fresh/frozen tuna to the United States, valued at $112 million.[18] Since the inauguration of the new Ministry of Maritime Affairs and Fisheries (MMAF) Minister in 2014, Indonesia has been embarking on a strategy to defend, promote, and expand fishing while tackling illegal fishing activities at the point of capture.

There is some evidence that Indonesian regulatory actors and major suppliers are prioritizing traceability in Indonesia. Traceability is an integral component of market commitments to authorized fishing. It is essential in seafood supply chains and offers the opportunity for governments to strengthen fishing management and for buyers to prioritize the purchase of responsibly caught fish. The estimated annual cost of Indonesia's illegal, unreported, and unregulated (IUU) fishing is between $3 billion and $5 billion a year, not including the additional costs of unattained tax income and damage to the ecosystem.[19]

Within the tuna supply chain, there appears to be an opportunity for tracking tuna from the fishing vessel in Indonesia to the point of sale in the United States. This could allow for regulatory actors such as the MMAF to better meet sustainability objectives in the prevention of IUU fishing at the point of origin and enable greater visibility of the tuna product as it moves through the supply chain. The application of blockchain technology can help enable these outcomes.

By adopting a blockchain traceability solution, tuna supply chain actors can increase their supply chain velocity by overcoming operational and market gaps and deliver sustainably caught fresh/frozen tuna to consumers with fewer health and safety risks and less product spoilage. Such a solution has the potential to significantly reduce unauthorized fishing and drive business value. Current risks in the supply chain that are associated with a lack of accountability and transparency, mislabeling of products, and poor cold chain management could be mitigated by the implementation of a blockchain traceability solution.

In today's global tuna supply chain, business risks are heavily weighted toward the downstream phases in the supply chain. Risks accumulate as tuna is harvested, produced, traded, and exported, which impacts what is distributed in bulk to the consumer. Across a web of supply chain actors, the time it takes for tuna to reach the end consumer after being initially caught is neither transparent nor optimized.

Due to the complexity of tuna supply chains in Indonesia and the transfer of tuna across multiple hands, poor cold chain management is common and post-harvest tuna product losses are high. Post-harvest losses can include tuna that does not reach the market for consumption and the reduced value of tuna due to poorly handled fish.

In Indonesia, harvesters, producers, and traders range in size, operations, and sophistication. Currently, there is a lack of uniform requirements and standards for traceability data and supply chain transactions comprise of a series of unique, short-term transactions across a web of supply chain actors. This drives up the cost of data management for each business in the seafood supply chain and increases the risk for errors, disputes, and inability to trace tuna products. Moreover, the complexity of transactions and documentation increases with fish brokers, middlemen, and transporters in the current supply chain.

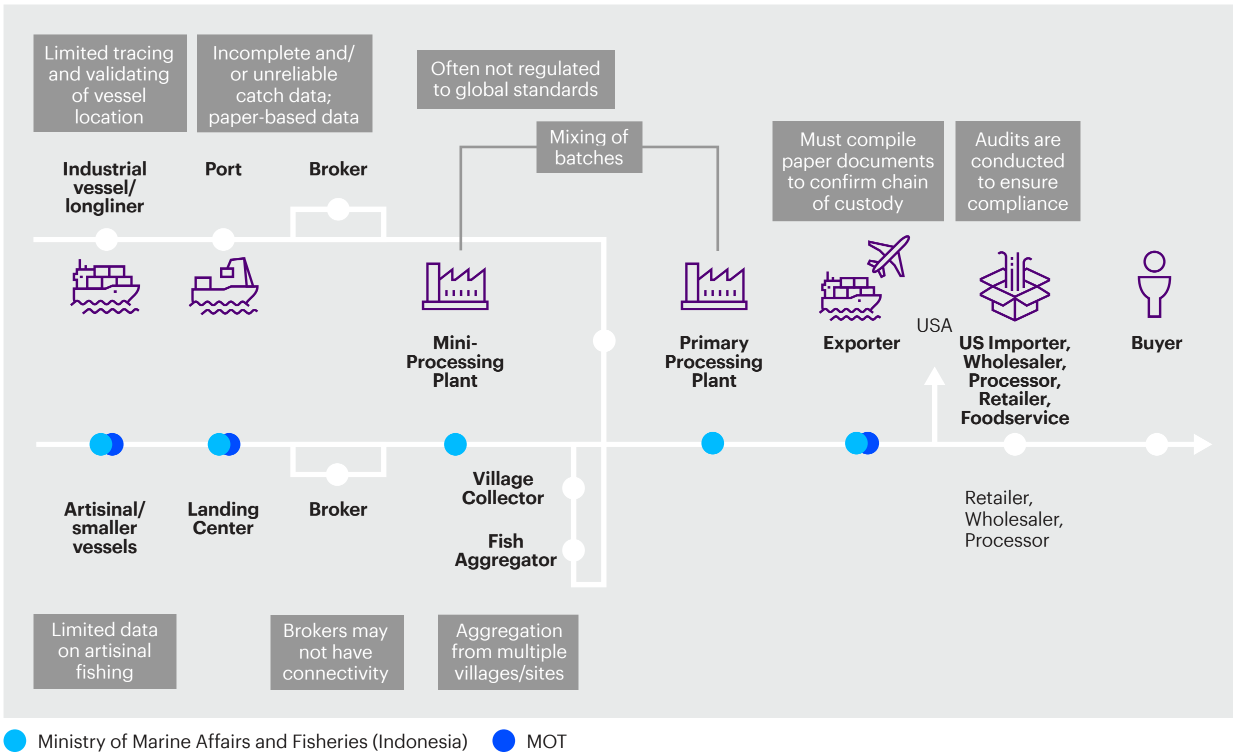
To increase supply chain velocity, blockchain traceability can enable businesses to collaborate in monitoring the performance of supply chain actors, identify inefficiencies, and reduce operational gaps. With the improved velocity, businesses can benefit from reduced costs associated with storing tuna for extended periods of time and discounting a tuna product due to longer times in the supply chain.

In addition, data transparency and the opportunity to leverage more advanced analytics can provide seafood businesses with the information they need to make better business decisions. Price data, for example, could allow upstream supply chain actors to better negotiate price and receive a greater portion of the final price from the consumer. Due to high margins, the opportunity exists for producers to increase their prices without much impact to the final retail price.[20]

Indonesian regulators, such as the MMAF, are also working toward regulations around responsible fishing practices, such as preventing IUU fishing and strengthening fishing data. In 2014, MMAF banned foreign fishing boats from Indonesian waters and took additional measures to prevent unauthorized fishing.[21] The benefits of authorized fishing compliance could be realized through increases in catch volume and prices for tuna products. Research conducted on the effects of Indonesia's anti-IUU fishing efforts suggest that Indonesian skipjack tuna fishermen "would lose 59% in catch and 64% in profit by 2035," "if an open-access fishing regime was maintained and no anti-IUU policies were implemented in the country (Indonesia)."[22] The same study finds that, "fishermen could enjoy a 14% increase in fish catch by 2035, and 12% rise in profit compared to current level," if "the government continued to curtail IUU fishing and cap harvests at maximum sustainable levels."[23]

Key traceability challenges exist in the current Indonesian wild-caught, fresh/frozen tuna supply chain. Indonesian wild-caught, fresh/frozen tuna moves through diverse actors in the supply chain from the point of capture to the point of sale to the consumer. Key technical and operational challenges to the rollout of blockchain-enabled traceability currently exist in this supply chain, including a lack of product segregation; unavailable, unreliable, and/or unstandardized data; and limited technology capacity for Indonesian actors.

Figure 5: Current Indonesian wild-caught, fresh / frozen tuna supply chain process map



KEY CHALLENGES

- Low tech, predominately paper-based documentation
- Limited and/ or unreliable catch data at landing sites
- Mid- to small-size fishing vessels with limited tracking technology
- Multiple instances of brokering and amalgamating, especially for catches from smaller/ distant ports
- Non-segregated supply chains with instances of re-batching, specifically at processing facilities
- Lack of standardized approach to data, labelling and units of measurement

Source: Accenture Stakeholder Analysis

Of the four commodities in this report, tuna was found to be the most feasible. With some level of technical and operational effort that can be incentivized through market and financial opportunities in the Indonesian wild-caught, fresh/frozen tuna supply chain, an end-to-end blockchain-enabled traceability solution can be feasible. Detailed analysis of key challenges along the supply chain demonstrates low to medium complexity, with minimum to moderate effort required to enable end-to-end traceability in the supply chain.

The most significant challenges in digitizing product traceability exist at the beginning of the supply chain, where fishing vessels, ports and landing centers, and brokers operate with little to no current enabling technology. The volume of actors and limited coordination of relationships at this early point in the supply chain mean that investment and introduction of a blockchain traceability solution requires significant effort to vertically integrate to create more consistent supplier relationships and to digitally transform the transaction processes of these actors.

Along the supply chain, moderate technical effort is required to digitize existing paper-based documentation, introduce RFID tagging technology, adopt segregated supply chain processes, build mobile applications for low-tech actors, and integrate existing enterprise platforms with a blockchain solution. The production and transport processes for fresh/frozen tuna are relatively simple, and thus, the associated operational efforts around shifting processes and training users are moderate as well. From processing facilities until the product reaches the consumer, actors appear to be largely using enterprise resource management (ERP) or other accounting and demand management technology that, with some effort, could be integrated with a traceability solution.

One known blockchain pilot for tuna was developed by WWF-Australia, Fiji and New Zealand, ConsenSys, TraSeable, and Sea Quest Fiji Ltd. This pilot combined mobile, blockchain, and smart tagging to track responsibly caught tuna from catch to consumer, aiding proof of compliance to standards along the chain.[24]

Required investments in these technical and operational efforts can be incentivized through market and financial opportunities. As demand for wild-caught, fresh/frozen tuna in the United States continues to rise[25], there is an opportunity for actors across the supply chain to receive the financial benefits of compliant tuna products that are already of high value in the global fish market. The seven most commercially important tuna species, for example, are among the most economically valuable fishes on the planet.[26]

Benefits and value drivers of a blockchain traceability solution could include more streamlined data sharing and improved confidence in catch data (e.g., to know if tuna was caught in legal waters), company brand enhancement for IUU-compliant products, and a clearer business case for investing in such enabling technologies as RFID tagging that could improve automation and streamline operations (and that could be justified for higher-value catch such as tuna).

THAI FARMED SHRIMP

Aquaculture is the fastest-growing form of protein production globally,[27] averaging an annual growth rate of 7% over the past two decades.[28]

Shrimp is a key global aquaculture product; it is the most traded global seafood product by value. As of 2013, production from shrimp farms accounts for 56% of global shrimp production.[29] In the United States, the world's single-biggest seafood importer, shrimp is the most consumed seafood per capita. Thailand is a top 5 contributor to global farmed shrimp production, accounting for approximately 17 20% of total U.S. seafood imports.[30] It is estimated that there are over approximately 20,000 actors in the farmed shrimp supply chain in Thailand, with shrimp farms making up the greatest order of magnitude.[31]

While the Thai shrimp aquaculture industry has the potential to reduce unauthorized fishing and increase shrimp production, it relies on wild capture to produce feed. In recognition of diminishing marine-capture fisheries, many countries have turned to aquaculture to reduce overfishing and depletion of wild fish stocks while increasing fish supply. However, as small-scale extensive aquaculture is being increasingly replaced by large-scale intensive aquaculture, the industry's share of global fishmeal and fish oil consumption has expanded significantly. This heavy reliance on wild capture could reduce wild populations significantly, despite the measures being taken to reduce overfishing.

There is evidence of a supporting ecosystem in Thailand for promoting traceable product. Because of repeated disease outbreak, increasing ecological problems, evidence of forced labor in the shrimp supply chain, and criticism from both nongovernmental organizations (NGOs) and consumer countries, progress is being made to strengthen regulations by domestic, exporting, and importing country governments.

For example, the U.S. National Oceanic and Atmospheric Administration (NOAA) requires that all imports for seafood products covered by the Seafood Import Monitoring Program (SIMP), including farmed shrimp, must comply with established reporting and recordkeeping requirements to prevent illegal, unreported, and unregulated and/or misrepresented seafood from entering U.S. commerce.

Although the legal and regulatory mechanisms required to enforce responsible fisheries are not yet in place, the Royal Thai Government is preparing to declare Thailand free from IUU-aquatic animals and fisheries products; the IUU-free Thailand initiative was adopted at the meeting of National Fisheries Committee on 25 January 2018 and is currently pending Cabinet approval,[32] indicating a potential positive commitment to reform the country's fisheries system with a view to promote responsible fisheries.

In addition to being high on the government's radar, companies based and operating in Thailand have been collaborating through the Seafood Task Force, an industry-led, multi-stakeholder alliance set up to help ensure that Thailand's seafood supply chain effectively addresses risks in the farmed shrimp supply chain, including the issues of forced labor, human trafficking, and IUU fishing through traceability, transparency, and verification.

A blockchain traceability solution has the potential to reduce health and safety risks in the shrimp supply chain by digitally recording chain of custody and capturing product and handling information.

Increasingly, companies are turning to traceability technology as a tool to reduce health and safety risks, limit costs, and enhance their brand. Current risks in the supply chain associated with a lack of accountability and transparency, such as mislabeling of products and poor cold chain management, can be mitigated with the implementation of a blockchain traceability solution that can digitally record the chain of custody and other key product and process information.

As risks to product integrity and safety become compounded as farmed shrimp is harvested, produced, traded, and exported, end-to-end traceability can provide some benefits to large wholesalers and retailers at the end of the supply chain. These companies also often exert significant influence on the supply chain and have the technology capacity to invest in and adopt such solutions.

As global demand for shrimp began to skyrocket in the 1980s and '90s, Thailand's shrimp aquaculture sector developed "intensive" farming methods, which stocked shrimp at high densities to boost yield.[33] However, some of the intensification process made farms more susceptible to diseases like White Spot and Early Mortality Syndrome (EMS), which have decimated shrimp populations on several occasions since 2011. Some farmers lost their entire crop within a matter of days, causing the price of shrimp to surge and Thailand to lose over $1.5 billion dollars in exports in 2013 alone.[34]

Contamination and product damage during shipping, handling, and processing pose additional significant risks to consumers. Ensuring that products do not encounter harmful bacteria and are kept at an appropriate temperature to avoid spoiling is critical. Post-harvest losses from spoilage happens when food is degraded such that it becomes unfit for human consumption. Mitigating risk of disease requires appropriate pond management, sourcing of healthy brood stock, and appropriate handling and transport. A blockchain traceability solution can provide additional visibility so that liability risks can be better managed, particularly in the cases of post-harvest losses and product recalls. In addition, issues with shipments, product damages, delays, health concerns, and other points of failure can also be improved with greater accountability and transparency, thus reducing the time and cost of issue resolution.

Currently, supply chain transactions comprise of a series of unique, short-term transactions across a web of supply chain actors. This drives up the cost of data management for each business in the seafood supply chain and increases the risk for errors, disputes, and inability to trace shrimp products. A blockchain traceability solution can allow data on shrimp products to be shared across actors, providing businesses the opportunity to reduce data and document management costs, including contracts, bills of lading, way bills, and transaction ledgers, and lower the potential costs associated with fixing errors and managing reconciliation and other disputes.

Furthermore, such solutions can enable businesses to collaborate to monitor the performance of supply chain actors, identify inefficiencies, and reduce operational gaps to increase supply chain velocity. With improved velocity, businesses can benefit from a more demand-focused approach and reduce the cost of storing shrimp for extended periods of time and discounting a product that reaches the retailer too close to an expiration date.

Uniform product data can also help businesses to better collaborate across the supply chain and show evidence of their sustainability commitments, so they can satisfy demands and better position themselves in the market.

Finally, a significant driver for businesses to adopt traceability is compliance with regulatory requirements, including domestic fishery laws and export and import regulations. Global regulations are the primary drivers for food safety compliance and currently, many businesses have their own internal tracking mechanisms in place to ensure food safety during their handling of shrimp products. By complying with food safety regulations, businesses have access to global markets where their products can be distributed.

Key traceability challenges exist in the current Thai farmed shrimp supply chain. As Thai farmed shrimp moves from point of capture to point of sale, there are key technical and operational challenges to enabling a blockchain-based traceability solution across diverse supply chain actors. These challenges include a lack of product segregation with instances of mixing batches and re-batching shrimp products, low technology capacity for Thai actors, and a lack of a standardized approach to tracking data, units of measurement, and labeling products.

In the short term, an end-to-end blockchain-enabled traceability solution may not be feasible in the full Thai farmed shrimp supply chain. However, a solution from shrimp farm to consumer is feasible with the appropriate incentives in place to maintain separation and segregation of shrimp. Significant effort is required to rollout a blockchain-enabled traceability solution in the Thai farmed shrimp supply chain at the fish processing plant and byproduct broker. The main product for these actors is fish, but they also sell the fish byproduct to animal feed producers. Technical and operational feasibility is highly complex at this stage, as net new processes, including segregation, and enabling technologies would have to be put in place to enable traceability of byproduct.

Further, considering the relatively low value of byproduct relative to the whole or portioned fish, financial and market feasibility of introducing byproduct tracking and segregation is low. Thus, there is little market incentive for fish processors to invest in the corresponding effort required to adopt new processes, technologies, user capabilities, and behaviors for byproduct tracing.

Further, a major challenge to ensuring traceable Thai farmed shrimp product in the supply chain is aquaculture feed production. There does not appear to be a widely accepted understanding of traceable aquaculture feed, and the supply chain is not fully connected to wild capture fish products, specifically fishmeal and fish oil, which are used for feed. Significant technical and operational effort would be required to link these supply chains and ensure traceable shrimp product; there are currently limited market or financial incentives for these low-value byproducts.

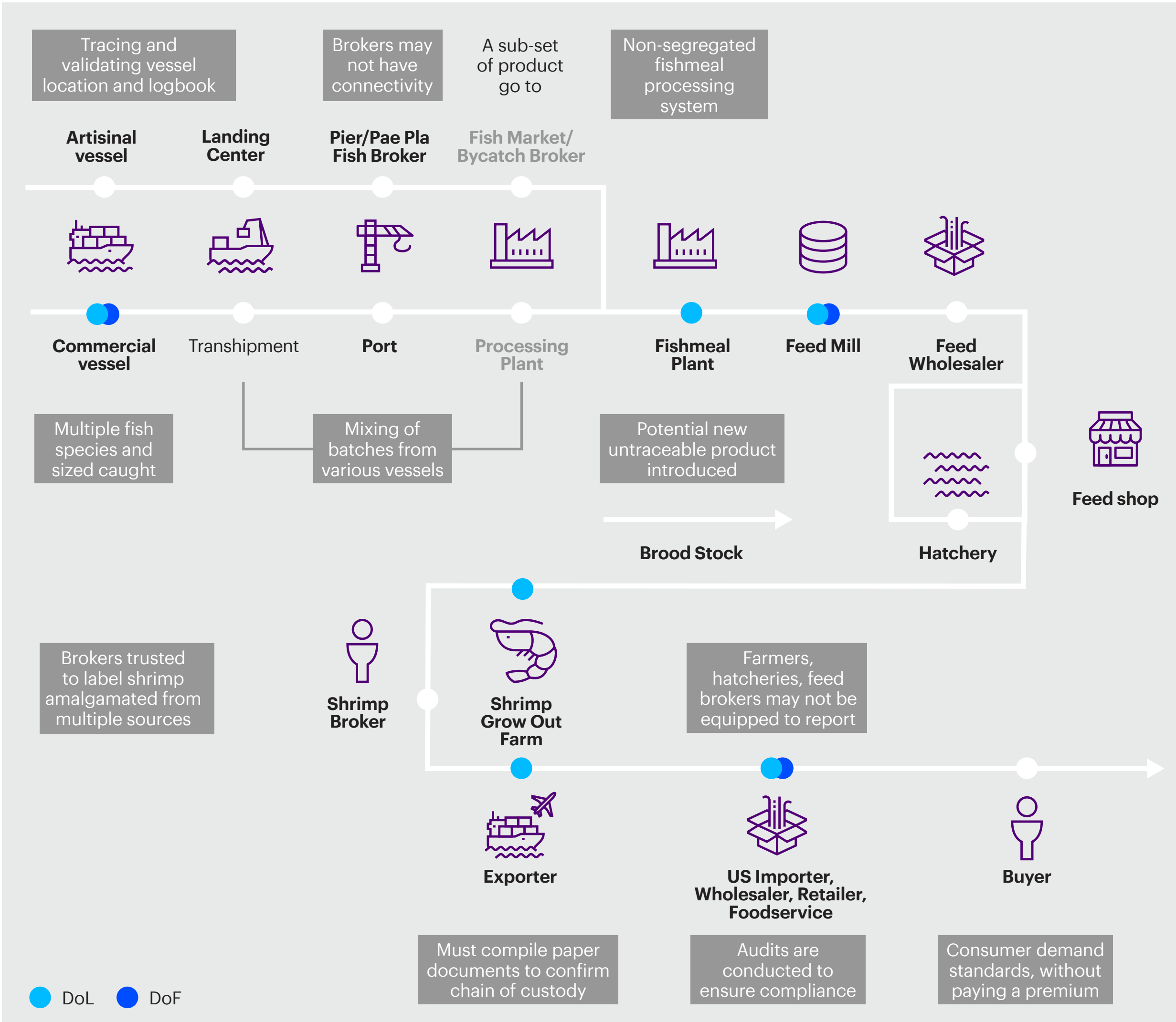
While tracing shrimp feed to its point of origin is very difficult, a blockchain traceability solution could be used to trace shrimp from farm to consumer. Starting at the shrimp farm, technical and operational feasibility is medium, requiring moderate effort to maintain separation and segregation of shrimp in batches from the various points of origin during farming, harvest, and through the processing phase. Moderate technical effort is required to introduce basic traceability technology at the level of the shrimp farm as well as to integrate existing shrimp processor enterprise platforms with a blockchain solution or to build mobile applications to connect to the blockchain.

From an operational perspective, moderate effort is also required to establish new processes, efforts, and capacities to close and segregate production processes. There is already some vertical integration between brokers who are contracted by processing plants and wholesalers to harvest shrimp and amalgamate the product for processing, therefore requiring less operational effort to coordinate the adoption of new technology and production methods. From processing facilities until the product reaches the consumer, most actors are using enterprise resource management (ERP) or other accounting and demand management technology that, with some effort, can be integrated with a traceability solution.

Moderate market and financial incentives for producing ethical and sustainable shrimp are required to incentivize these investments.

Benefits and value drivers of a blockchain traceability solution include improved data sharing and visibility on whether products were appropriately segregated, company brand enhancement for IUU-compliant products, and streamlined auditing.

Figure 6: Current shrimp supply chain process map



KEY CHALLENGES

- Low tech, predominately paper-based documentation
- Ships >20K tons require Vessel Monitoring Systems, <20k tons are on an honor system
- Multiple instances of brokering and amalgamating throughout the supply chain
- Non-segregated supply chains with many instances of mixing batches and re-batching
- Brokers and farmers may not be equipped to complete required reporting
- Lack of standardized approach to data, labelling and units of measurement

Source: Accenture Stakeholder Analysis

BRAZILIAN SOY

Brazil is one of the world's largest producers of soy and the single-largest supplier of soy products to China. Soy is often referred to as the "King of Beans." It is the fourth-largest crop produced globally by volume and is pervasive in our food products as well as in the diets of our livestock.[35] Soy production and consumption has been increasing for decades and is expected to continue accelerating as growing populations and economic development demand more meat, dairy, vegetables, fruit, and fats.

The United States, Brazil, Argentina, and China are the world's largest producers of soy. Brazil now exports 60% of its harvested soybean crop[36] with 75% of it going to China.[37] Furthermore, 70% of soybeans exported from Brazil are sent as whole beans[38] and then further processed into meal and oil once it reaches facilities in China.

Soy production is a large contributor to deforestation, and in Brazil, it is the second-largest cause of deforestation after cattle ranching.[39] Due largely to international interest in forest conservation, Brazil has strict environmental land-use regulations that were passed through a series of Forest Codes. For example, landowners in the Amazon region can only farm on 20% of their land and must maintain the other 80% as forested land.[40] The 2012 Brazil Forest Code mandated the use of a land mapping registry system, known as Cadastro Ambiental Rural, or CAR, but only 1.4 million out of 5.5 million properties had been registered by the 2015 deadline.[41]

There has been much interest in soy traceability, owing largely to international environmental concerns and pressure, and the subsequent government and corporate interest in compliance. The Brazilian government has collaborated with industry associations and stakeholders to remove non-compliant products from the supply chain. Brazil's Soy Moratorium was the first voluntary zero-deforestation agreement implemented in the tropics and set the stage for supply-chain governance of other commodities, such as beef and palm oil.[42] In response to pressure from retailers and nongovernmental organizations (NGOs), major soybean traders signed the Soy Moratorium, agreeing not to purchase soy grown on lands deforested after July 2006 in the Brazilian Amazon.[43] Large international processors have also been independently experimenting with traceability systems.

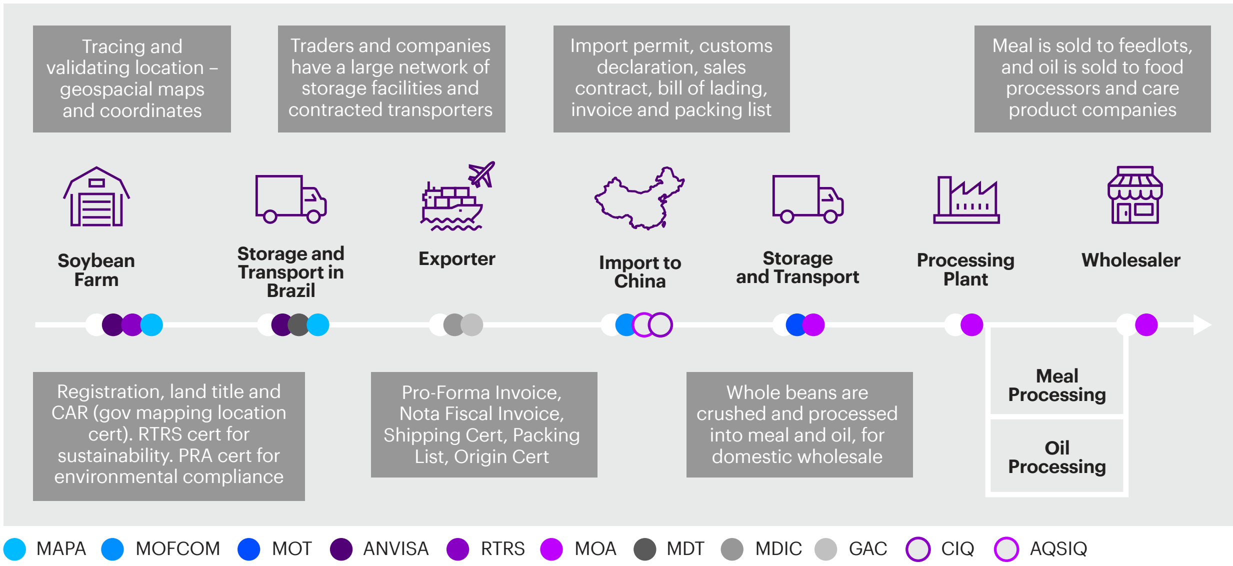
In addition to managing risk and regulatory compliance with Brazil's Forest Code and Soy Moratorium, a blockchain traceability solution can help soy supply chain actors realize business value through greater visibility across suppliers for managing production volume and economies of scale needed to meet global demand more efficiently. The profitability of soy-producing companies is linked to their production volume, which requires economies of scale to keep grain elevators, rail cars, barges, and cargo ships busy and generating revenue.[44] Volume itself is dependent on retail, which is increasingly influenced by factors such as food safety and consumer confidence. As a result, an increasing number of firms are exploring innovations in traceability, and capital investments are frequently necessary to maintain a competitive edge in a constantly changing technological landscape.

Furthermore, actors across the global soy industry face challenges common to all supply chains, including cost inefficiencies, accountability and transparency, market competitiveness, and risk management. In Brazil, there are a wide variety of logistics agencies handling the transport and storage of soybeans, all of which require separate transaction documentation and contracts. Every day, approximately 10,000 trucks leave Mato Grosso, the largest soy-producing state in Brazil.[45] Grain sellers and traders will contract either transport services directly or transport agencies who then subcontract. An estimated 50% of all transport services are provided by self-employed drivers.[46] Moreover, while storage bags are increasing in popularity, on-site storage is still not very common in Brazil, with only 14% of rural producers with warehouses located on their farms.[47] This necessitates frequent contracting with storage and transport providers, plus significant numbers of contracts, bills of lading, way bills, and transaction ledgers also need to be maintained. Such data reconciliation can expose companies to risk and additional costs, if documents become out of sync, leading to potential disputes or difficulty in tracking information about business performance.

With a dense network of third-party actors and relationships to manage, producing firms and processors often end up with lower margins than expected. Disputes are time-consuming and complicated to handle, and traders or brokers are often used to assist in relationship management, bringing their own costs. These costs are exacerbated by the perishability of soy, which has time limits and conditional requirements on storage and transport. This can result in delays, lower prices, or actual waste, as delays in the supply chain bring products closer to their expiration dates. Blockchain technology can offer a possible solution to capture and share data on the movement of goods, as well as contract management. It can also potentially enable shared inventories to better align buyers and sellers and reduce dependency on brokers.

Key traceability challenges exist in the current Brazilian soy supply chain. In the current soy supply chain, the buyer is responsible at the first point of sale for determining whether they are introducing sustainable soy into the product chain, which they determine by checking whether the farm they are buying from has its CAR registration. As soy moves from the first point of sale to the final point of sale to the consumer, there are additional technical and operational challenges. These challenges include a lack of standardization around data, labeling and packaging, and units of measurement, low technology capacity for select actors, and the mixing of batches and re-batching of soy products. In addition, soy is used for a wide variety of end products across industries (meal, oil, etc.), but tracking soy through to its end product is particularly challenging.

Figure 7: Current Brazilian soy supply chain process map



KEY CHALLENGES

90% of the farmers own 20% of the land – large farms are constantly expanding and purchasing new land.

Many different handlers in Brazil and China, could be thousands of trucks on the road in a given day.

Large processing firms lack incentive to share data. Sustainable soy is still a niche product.

Batches inevitably mixed unless segregated. Very wide variety of end products across many industries.

Brokers and farmers may not be equipped to complete required reporting.

Lack of standardized approach to data, labelling and units of measurement.

Source: Accenture Stakeholder Analysis

A blockchain-enabled traceability solution can be feasible in the soy supply chain but would require significant up-front effort and coordination. Analysis of the soy supply chain demonstrates primarily low to medium complexity, with minimum to moderate effort required to enable end-to-end traceability.

At the farm level, actors are low tech and moderate effort would be required to reach a significant number of soy producers and introduce traceability technology. Since there are established and consistent relationships between soy farmers and soy brokers that amalgamate harvested beans, the brokers may be a more appropriate target to accelerate the introduction of traceability technology and avoid having to introduce the technology at the farmer level. Brokers also play an important role in gatekeeping sustainably sourced soy that is compliant with the Soy Moratorium. A farm's CAR registration, for example, could be validated by the broker at the first point of sale to confirm farm compliance. If brokers can ensure that their contracted storage units do not mix compliant and non-compliant product, it would be possible to differentiate between compliant and not fully compliant soy product.

In tracing the product through multiple transactions between supply chain actors, moderate technical effort is required to digitize existing paper-based documentation, build mobile applications for low-tech actors, and integrate existing enterprise platforms with a blockchain solution.

One of the most significant obstacles to tracing soy to the originating farm is that it is amalgamated and mixed at the storage and shipping stages. Soy is amalgamated by brokers and stored in grain silos before being further amalgamated into a large hull of a transport ship. Therefore, to ensure compliant soy reaches the processing actors in China, brokers must ensure that only compliant soy reaches their storage silos and that there is a high enough volume of compliant soy (and that only the content of purely compliant storage silos) to be mixed together and transferred into the hulls of transport vessels.

At the processing stage, there is a medium level of complexity required to adopt separate or segregated production and maintain unique identity of soy products in lots or batches identified by source. For processors crushing soybeans and blending it into soy meal and oil, maintaining unique identity can be challenging, and require standardized tracking, labeling and packaging, and barcoding, as well as new processes, efforts, and capacities to close and segregate production processes and track identity by supplier.

Market and financial incentives would need to be put in place to incentivize these technical and operational efforts. Sustainable soy is still a niche product, and the financial benefits may not be reaped as easily as they would be for a higher-value product, such as tuna. A small premium for sustainable, traceable soy products or having a preferred vendor relationship could be sufficient to enable some investment in technologies and training required, but further exploration is required. For greater segregation and new processes to track the identity of soy at the processing plant, supporting regulations and incentives from U.S. importers (such as wholesalers) can support the investment required if sustainable end products that leverage soy are valued highly in the market

Benefits and value drivers of a blockchain traceability solution include improved data sharing and visibility on whether batches of soy were mixed, brand enhancement for companies whose soy products do not lead to deforestation, and streamlined reporting for compliance among actors.

BRAZILIAN PROCESSED BEEF

Brazil is the largest exporter of beef.[48] Brazil is the largest exporter of beef in the world, with roughly 1.44 million metric tons exported in 2017.[49] Brazil currently supplies about a quarter of the global beef market.[50]

Due to inefficient land usage in cattle ranching, the industry in the Brazilian Amazon is responsible for one in every eight hectares of forest destroyed globally.[51] Over 60% of all Brazilian cows are currently grazing on deforested land.[52] With the economies of the world's largest beef importers, particularly Russia and China, growing every year, the need for additional land to raise cattle is expected to increase.

Over the last two decades, there have been a wide variety of efforts to improve environmental conditions in the Amazon, decreasing the annual deforestation rate by almost 59% from 2004 to 2016.[53] Built upon previous Brazilian legislation to reduce deforestation, including the 2012 Forest Code, the Working Group for Legal Amazon and the TAC Commitment have worked with meatpacking companies to reduce non-compliant beef suppliers by implementing and enforcing the regulations, working with law enforcement by sharing supplier lists with geospatial maps twice a year in addition to consenting to annual independent compliance audits,[54] and demanding that suppliers follow TAC Commitment standards.

In response to growing international concern around deforestation and climate change, many actors involved in the cattle trade have begun to investigate the potential for beef traceability to promote sustainability goals. In 2002, the European Union began to demand traceability for its fresh beef market, which resulted in Brazil's national identification system and the Certification of Bovine and Bubaline Origin (SISBOV) program.[55] While this system was entirely voluntary, it was the first attempt within the country to create unique animal IDs and digital certifications of farms that could be stored and traced electronically. However, it was not widely used. By 2015, only 628 (0.05%) of the farms with more than 50 cattle had agreed to comply with the program.[56]

Since most farms in Brazil still do not track individual cattle with any form of unique identification (e.g., RFID), any adoption of a traceability program would require additional costs to set up and maintain new infrastructure. The domestic markets, however, have shown great interest in traceability. About 62.4% of polled Brazilian customers favor mandatory beef traceability in the country and are willing to pay for it, and 86.6% disagree with the traceability programs only being instituted for foreign destinations.[57]

Additionally, with several food-sanitation scandals surrounding the Brazilian beef industry in 2017, many key importers, including the United States, have placed bans on fresh beef from Brazil. Allegations of food sanitation inspectors taking bribes for either allowing rancid products or simply not inspecting meatpacking facilities at all have harmed public trust in Brazilian beef products and increased the interest in greater visibility into the beef production supply chain in the country.[58]

The only legally required traceability system that currently exists in Brazil is the Animal Transit Guide (GTA in Portuguese), which accompanies cattle lots as they move from one farm to another.[59] This document confirms the start and end of a cattle transaction but does not contain information about anywhere else that the cattle may have been before the latest trade nor does it track cattle individually. If recorded digitally, the GTA has the potential to be cross-referenced with CAR registrations for sustainability tracing. The Agricultural Management Platform (PGA) maintained by the federal government stores aggregate GTA information that could potentially be interconnected with prior GTA data for more complete tracking and tracing of suppliers.[60]

To rebuild consumer confidence and meet Brazil and importing country regulatory requirements, beef supply chain actors could create greater transparency and auditability, manage health and safety risk, and create operational efficiencies using a blockchain traceability solution. Over the last few years Brazil's largest beef production firms' revenues have fallen because of a series of scandals and health concerns in 2017.[61] After several meat processors were caught bribing inspectors to certify spoiled or salmonella-infected meat, China, Mexico, Japan, Chile, the EU, and Hong Kong all took significant measures to avoid importing Brazilian beef.[62] The United States followed suit later that year, after finding that an abnormally high percentage of Brazilian beef shipments failed health inspections.[63]

With significant revenue at stake in banned fresh meat products and loss of consumer confidence, the Brazilian industry has begun to express greater interest in more widespread systems of accountability and quality attestation. Furthermore, recent studies indicate that improvements to inefficiencies in the beef supply chain could save hundreds of billions of dollars in energy costs and potentially reduce the estimated 42% of Brazil's total climate change for which the beef industry is responsible.[64] In general, with increased competition and decreased market shares, along with a variety of widely recognized problems and inefficiencies throughout the supply chain, major firms in the industry have incentives to embrace technological innovation. In the past, they have also shown interest and a strong ability to collaborate successfully on efforts for the public good, such as the Zero Deforestation Agreements.

Many of the inefficiencies in the Brazilian cattle trade involve animal production, beginning with food intake and weight gain involved in fostering animal productivity and growth.[65] While Brazil has the world's largest head of cattle, which is over eight times that of Australia, it fails to produce even four times as much beef as Australia.

The reason is largely due to slower speeds in turning over cattle at different points in the Brazilian supply chain, ultimately resulting in less slaughter and less product output per year.[66]

Blockchain technology and solutions present an opportunity to reduce many of the inefficiencies in the Brazilian beef supply chain. For example, the velocity of cattle through the supply chain could be improved with more direct contact between buyers and sellers and less dependence on brokers and intermediaries. This improvement could ultimately increase the percentage of Brazil's cattle ready for slaughter each year. Additionally, better insights from cattle producers and grain producers into each other's inventories could lower the costs of raising cattle and potentially help increase the percentage of cattle being raised on forms of animal feed, allowing cattle to be slaughtered younger and heavier with increased yields, consistency, and quality. It could also reduce the competition for land with the grain industry.[67]

The risks borne by the Brazilian cattle industry are mainly centered around health and safety concerns, primarily viruses that have been found in animals and end beef products. In the current supply chain, there are many animal and carcass handlers, and it can be difficult to determine where the meat became contaminated, particularly for any blended or mixed products. Even if the inflection point can be determined, it can be very difficult to recall products because there is limited visibility into animal and product movements throughout the supply chain and the country.

This lack of trust, along with shipment denials and corresponding legislation restricting Brazilian imports to many countries, has lowered revenues and raised risk across the supply chain. Blockchain-enabled traceability for cattle and beef products could present a great opportunity to confirm health and safety, to assign liability if and where health issues arise, and to flag and recall products that have been through particular institutions or contamination-causing conditions. It could also make it simpler to ensure products through the supply chain and reduce the risk of shipment denial at entry inspections.

Additionally, consumers around the world are increasingly concerned with the sourcing and responsible production practices of their food products. According to the global Unilever study previously discussed in this report, a third of consumers are now choosing to buy from brands they believe are doing social or environmental good.[68] The report concludes that sustainability and responsible sourcing, while an attractive market differentiator now, is becoming an imperative for market viability. Blockchain traceability, in addition to restoring trust and confidence in Brazilian meat products, has the potential to help processing firms further differentiate their products and offer certification of superior attributes, such as sustainability.

Key traceability challenges exist in the current Brazilian processed beef supply chain. As Brazilian processed beef moves from point of origin to point of sale, there are significant technical and operational challenges to enabling blockchain-based traceability across diverse supply chain actors. Cattle may go through several different farms and ranches before reaching a slaughterhouse. One of the major challenges at this stage is a lack of segregation at the cattle level. Cattle is largely tracked in batches through GTAs, and re-batched at each farm or ranch where a GTA may be discarded and a new GTA is created. Additional key supply chain challenges include low technology capacity for Brazilian actors; a lack of a standardized approach to tracking data, units of measurement, and labeling products; and issues with fraudulent products.

Of the four commodities in this study, beef was found to be the least feasible, and would require significant effort to align market incentives. For a starting point, consider a use case beginning from the point of origin to abattoir in the beef supply chain. Analysis of key challenges along the beef supply chain demonstrates medium to high complexity, with moderate to significant effort required to enable end-to-end traceability in the supply chain.

At the farm level, actors are low tech and a moderate effort would be required to reach a significant number of cattle producers and introduce traceability and RFID technology to trace each individual animal in a transaction. Currently, cattle are often transferred in groups between multiple farms before reaching the abattoir. The only transaction documentation is the GTA, which does not currently appear to enable tracking of individual animals. In addition to the introduction of tagging technology, effort is required to digitize the CAR to confirm that the farm is compliant with the Forest Code as well as the GTA to digitally log the transfer and include identity information for each individual animal when transferred from one farm to another.

Throughout the supply chain, moderate technical effort is required to digitize existing paper-based documentation, introduce tagging technology (such as RFID), build mobile applications for low-tech actors, and integrate existing platforms with a blockchain solution. During the production phase, cattle undergo a significant transformation in identity from the cattle farm to the consumer, passing through many steps of processing. Thus, operational complexities in tracing beef are high, and moderate to significant effort is required to establish new processes and training to trace beef as it undergoes processing with diverse actors.

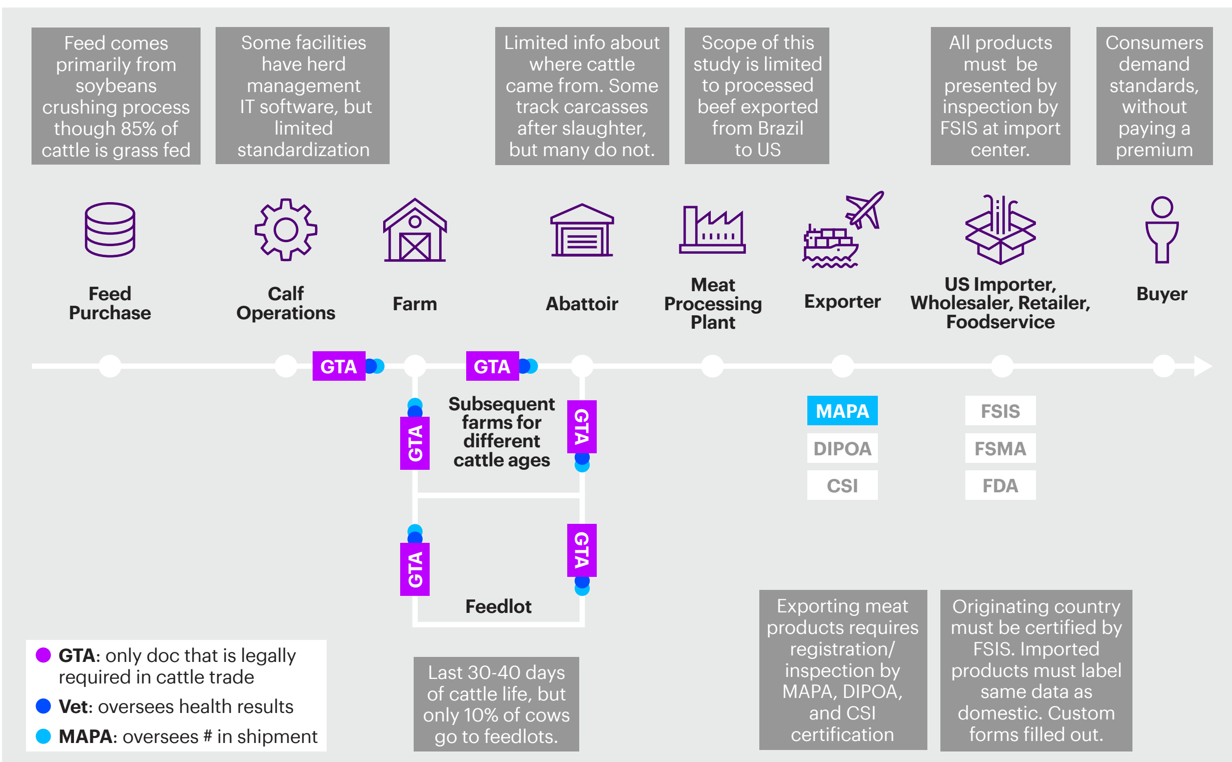
From a market and financial perspective, as beef is cut up, the high-value beef is separated from the low-value byproduct, and there appears to be little incentive to invest in the traceability for byproduct without also investing in traceability technology and infrastructure for the higher-value product. Processed beef therefore lacks well-aligned market and financial incentives to invest in moderate to significant technical and operational efforts of tracing beef in the short term.

A blockchain-enabled traceability solution from the point of origin to abattoir, or the point where the carcass and meat start to be separated, may be more feasible. Brazil has regulations that support point of origin traceability and zero deforestation practices, and thus, may be one starting point for further investment. Benefits and value drivers of a blockchain traceability solution could include strengthened audit trails, proof of authenticity (to combat fraudulent products), and improved data sharing and visibility to batch segregation.

Aside from the individual challenges of each commodity, there is no one size fits all in traceability solutions. There are many different types of traceability solutions in the market, each having a specific focus and serving specific commodities and geographies. Supply chains are largely decentralized and non-integrated, and they involve several diverse actors with only ad hoc or opportunistic relationships with each other. Moreover, technology is focused on the enterprise level, mostly ERP, purchasing, and inventory management software; it is not well suited for use among multiple partners as there is often mistrust among these partners or few incentives to share openly.

However, market pressure is now reaching the tipping point required to encourage investment in traceability. This is predominately due to the health and safety recalls of these commodities, which shifts the focus to processing points.

Figure 8: Current Brazilian beef supply chain process map



KEY CHALLENGES

- Low tech, predominately paper-based documentation
- Limited data is legally required to trade in live animals
- Multiple instances of new data creation and abolishing of data trails
- Non-segregated supply chains with many instances of mixing batches and re-batching
- Alleged high level of corruption – lack of trust for human entry or audit results
- Lack of standardized approach to data, labelling and units of measurement

Source: Accenture Stakeholder Analysis

PILOT PROFILES AND PRIORITIZATION

For this study, four key criteria were selected to help evaluate the feasibility of, and value provided by, a blockchain traceability solution for the four selected commodities and use cases.

- **Market feasibility and value:** The appropriate demand and market conditions are in place to enable participants in the market to be interested and beneficial to participate. The solution must provide demonstrable business value, and incentives for each participant in the blockchain ecosystem with sufficient value that each participant is expected to receive.
- **Technical feasibility and value:** The technology is a good fit for the industry and its actors' needs; these needs should be addressed directly through the key benefits that blockchain technology specifically brings, including its ability to allow multiple parties access to the same data.
- **Operational feasibility and value:** There is sufficient capacity and coordination to enable adoption. This would include a practical and manageable governance model for effective collaboration, as well as capabilities, processes, training, and the like, to put the solution into practice, and sustain and scale the solution.
- **Financial feasibility and value:** Introducing blockchain is financially feasible because the required capital is available to the actors who need it, and they can reasonably expect a return on investment either through revenue increase or cost savings.

Summary

While blockchain traceability solutions could be created for all four commodities, this study's findings indicate that certain use cases could be prioritized based on value provided and operational and market feasibility conditions. The design and development of the technology and technical solution are similar across use cases.
The complexity of combining blockchain with existing traceability applications need not be overly complicated. The least ideal use cases had significant operational challenges that are not currently offset by sizeable business value and market feasibility to make them investment ready.

Meanwhile, the best use cases have sizeable potential business value, which can offset some of the operational challenges of implementation. The four commodities listed in order of high to low feasibility are as follows:

Indonesian wild-caught fresh/ frozen tuna

With limited technical complexity, wild-caught fresh and frozen tuna has the attributes of a strong use case for end-to-end traceability. Wild-caught fresh/frozen tuna has a relatively high global price and high consumer awareness of tuna's overfishing and product quality. Relative to the other commodities under examination, tuna has a more linear supply chain with limited processing, a trackable product unit identity and increasingly aligned business and regulatory incentives. Tuna's identity can be traced effectively by individually tagging tuna with RFID tags until it enters a processing facility, as has been piloted in a few places already. From the processing facility onward, the whole or portioned fresh and frozen tuna can be packaged in a box with an affixed barcode that connects the physical and digital identity of the product contained in the blockchain until it is delivered to the consumer.

Thai farmed shrimp

Although an end-to-end blockchain traceability solution that starts with aquaculture feed may not be technically feasible at this time due to the additional complexity and scope of looking into feed, a blockchain traceability solution to track shrimp from farm to the consumer may be more feasible if the separation and segregation of shrimp can be maintained through processing. Blockchain-enabled traceability starting at the shrimp farm can allow for the tracking of shrimp produced in compliance with health and safety standards and maintaining a documented chain of custody to meet import regulations, such as the U.S.'s Seafood Import Monitoring Program (SIMP).

In terms of operational feasibility, the process of tracing the supply chain between farm and retailer has several relatively small, yet straightforward steps, which makes it more viable. There is some vertical integration between brokers who are contracted by processing plants as well as processing plants and wholesalers, therefore requiring less operational effort to coordinate the adoption of new technology and production methods.

Brazilian soy

In the case of whole soy beans sold to China for processing, piloting blockchain may enhance compliance with and enforceability of the Brazil Forest Codes and CAR registration because there is strong regulatory support for preventing deforestation. A soy blockchain pilot could cover transactions from farm to wholesaler. Due to the technical complexity of the corresponding supply chains for soy for human consumption, soy oil, soy for feed production, and others, it would be difficult to maintain traceability data as the product potentially gets further mixed and refined. Tracing whole beans until they reach the wholesaler is technically feasible and would allow processors to confirm they are purchasing whole beans from a sustainable source—where the sustainability and/ or commercial value may justify the investment and a “good enough” solution can be developed while other supply chain issues are being addressed.

Brazil has supporting regulations, and the Soy Moratorium creates disincentives, such as penalties and embargoes, for purchasers that get soy from farms contributing to deforestation (i.e., those without proper CAR registration). Therefore, using blockchain to trace soy with valid proof of proper CAR registration from farms to storage silos and beyond could create an incentive for purchasers of whole beans to confirm that their soy is compliant, regardless of the form it takes after processing.

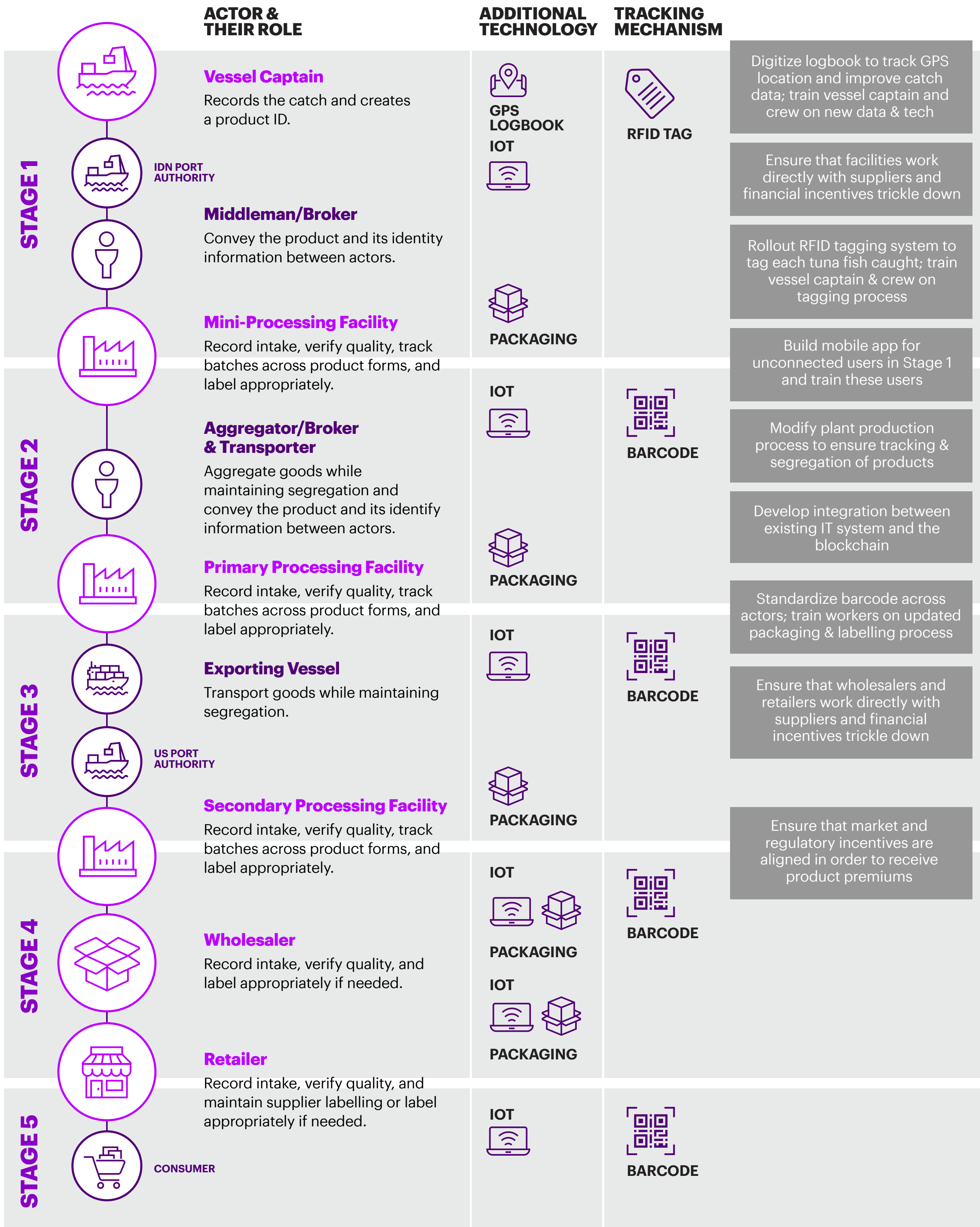
Brazilian processed beef

While the processed beef use case has low market and financial feasibility, there is greater potential value in creating a blockchain pilot to digitize the exchange of live cattle and validate its origin and chain of custody from the farm to the abattoir—the point where the carcass and meat start to be separated. Brazil has supporting regulations, and there has been some traction with companies to commit to zero deforestation practices. In other words, purchasers would avoid purchasing cattle from farms that contribute to deforestation (i.e., those without proper CAR registration). Therefore, using blockchain to trace individual cattle between farms and validate that all farms have proper CAR registration could allow Brazilian beef purchasers to confirm that their beef is compliant, regardless of the form it takes after processing. This could serve to the benefit of businesses trying to prove to regulators and consumers that their beef is compliant, and was grown sustainably, that is, it did not to contribute to deforestation.

Tracing the production process of beef beyond the abattoir is technically complex and the market incentives are not well aligned. Beef undergoes a significant transformation from the cattle farm to the ultimate consumer, passing through many steps of processing and exchanging hands many times, adding to its complexity. As it is cut up, the high-value beef is separated from the low-value byproduct, and there is very little incentive to invest in the traceability for byproduct without also investing in traceability technology and infrastructure for the higher-value product.

Note: Additional information on the scoring across the four criteria is available upon request.

Figure 9: We recommend a pilot across the end-to-end supply chain



Tradeoffs

With all the potential benefits that blockchain solutions can bring to supply chain management, there are also several challenges to be considered. First and foremost, the supporting infrastructure, that is, the tools, machinery, and enabling technologies required to pilot a blockchain solution, must be available to the required parties. For example, if the goal of a blockchain pilot is to track cattle through a supply chain, a traceability solution/platform that can assign individual animals an identifier would need to be available and implemented. In many supply chains, actors may not have access or resources to properly integrate existing technology and processes with the traceability application. Thus, it is important to consider at what point in the supply chain a pilot should take place to prove blockchain is able to deliver value. It is critical to consider a starting point as pilots to prove value should not be conducted on the end-to-end supply chain. It is important to learn from a pilot what is achievable before refining and expanding to the rest of the supply chain. Choosing a practical starting point in the supply chain is the key.

The creation of consortiums and associated governance models also pose a challenge to development of a blockchain for supply chain management.[69] Building a consortium of actors with suppliers, competitors, and others is complex and takes time and effort to design and implement. Operationally, it may prove quite different to how these actors engage today. For example, new models may be required to engage and align partners or new regulations may need to be developed to agree on competition, intellectual property, liability rules, and other aspects. Existing operating models and ways of doing business need to be thought through, and this effort should be factored into any implementation.

In a global network, coming to a set of standard data and formats to enabling sharing is challenging. It is important to decide among actors what is the common set of data that all participants need to access. Not all data needs to be shared and not all data should be shared and accessed by everyone. Agreeing on a small set of core data that would benefit all actors upon sharing enables focus on scope and a clear pathway to succeed, rather than getting stuck on numerous data attributes that could be shared. Creating this minimum viable data set will enable an easier path for pilots to take place and demonstrate business value. It is important to consider legal and compliance regulations and how the solution will be able to meet these. Compliance needs to be considered as part of the design to ensure that the solution is viable.

Most organizations will continue to use their current systems and might be hesitant to experiment with blockchain. As such, the true costs, innovative cost-sharing models, as well as a clear business case and incentives must be articulated to each of the participants. Incentives need to be compelling enough to justify migrating toward a blockchain-based approach and tailored to each party. Several organizations will likely be hesitant to change the status quo without seeing significant investments made across their industries. Many will at least want to see a minimum viable ecosystem for an implementation already in place before getting involved.

Lessons Learned and Potential Opportunities from Other Sectors

Blockchain pilots in food traceability are growing. The team explored case studies, featured below, related to the use of blockchain for fish, beef, grains, and other foods to understand the successes and failures. The following six case studies were the most relevant to our feasibility study and contained the most secondary information available for analysis.

Figure 10: Case study summary

	Provenance[69]	**WWF, Traseable, Sea Quest Fiji, Conensys**[70]	**Beefledger**[71]	**Belagricola, IBM**[72]	**Walmart, IBM**[73]	**Accenture, Bill of Lading**
Geography	Indonesia	Fiji	Australia	Brazil	Central America	United Kingdom
Commodity	Tuna	Tuna	Beef	Grains (incl. Soybeans)	Mangoes	12 containers
Platform	Unknown	Ethereum (hybrid) (ConsenSys Proof of Stake)	Ethereum with ERC20 smart contract (permission-less)	Hyperledger Fabric (permissioned) & smart contracts (IBM Agritech)	Hyperledger Fabric (permissioned) (IBM Food Trust)	Ethereum with permission layer on top (hybrid)
Summary	Mobile, blockchain, and smart tagging to track responsibly caught tuna and certifications/ claims from catch to consumer, aiding proof of compliance to standards along the chain	IoT / sensors, smart tagging, and blockchain to drive out illegal fishing, make supply chains fairer and aid instantaneous auditing	IoT, blockchain, analytics, smart contracts, and digital tokens to track provenance, streamline payments, mitigate fraud risk, and provide transparency in sustainability	IoT and blockchain to track grains stored in warehouses for quality assurance, with the goal of optimizing grain trading with global exporters	IoT and blockchain to track mangoes through the supply chain, from farm to consumer, with the goal of identifying provenance and improving food safety issues	Blockchain to record events and transactions across multiple parties in shipment, provide real-time track and trace to align shipper and carrier of the load movement
Key Nodes	Local NGO, fisherman, supplier, retailer	Fishery, processing facility, exporter	Cattle breeder, grazier, feedlot, cattle agent, transporter, abattoir, distributor, retailer	Cooperative producers, warehouse originator company, rural credit bank	Farm, packing house, import warehouse, processing facility	Exporter, forwarder, export port, carrier, import port, importer

	Provenance[70]	WWF, Traseable, Sea Quest Fiji, Conensys[71]	Beefledger[72]	Belagricola, IBM[73]	Walmart, IBM[74]	Accenture, Bill of Lading
Data Tracked	QR codes and NFC stickers, actor ID, location, attributes or certification, fishing method	QR codes and RFID chips, temperature, certifications, vessel #, weight, actor ID, time stamp	PO #, price, weight, actor ID	Grain quality (ex: moisture level), actor ID	Batch number, farm origin, factory data, expiration date, shipping details, food safety audits / certificates	Data attributes across data sheets (e.g. bill of lading)
Key Impact	Not quantified	Not quantified	Not quantified	15% GM-free Soybeans added value (anticipated)	Traceability to point of origin went from 7 days to 2 seconds	Data attributes can be reduced by approximately 80%

Source: Accenture Stakeholder Analysis

Key Learnings

The summarized learnings below inform the recommendations on how blockchain can be rolled out across supply chains to enable traceability:

Developing a successful blockchain initiative requires identification of the right use case and involvement of a group of parties that can align their incentives

To reap the full business benefits of a blockchain supply chain network, a group of actors in the ecosystem needs to be aligned and engaged, ideally forming a consortium. In the Bill of Lading concept, the consortium parties included a global product manufacturer, a freight agent or "shipper," an ocean freight carrier, a customs agency, and Accenture, the blockchain administrator. A clear value proposition was presented to all.

Existing paper-based and repetitive documentation is costly, slow, inefficient, and error-prone—up to 70% of data is replicated. Blockchain allowed for clarity in transparency of information to relevant parties in near real-time, thus significantly improving efficiency, streamlining processes and speed of operations, lowering the efforts in meeting customs compliance requirements, and improving accountability. Ultimately, the client's managed data attributes dropped from 38 to 7 that were critical to all parties in the blockchain network.

Other solutions have established consortium business networks across the food commodity ecosystem. For example, Belagricola and IBM's grain quality assurance tracking solution was composed of a Grain Exporters Business Network (GEBN) and a diverse set of players, including grain producers, rural credit cooperatives, warehouse companies, trading exporters, agrochemical companies, freight forwarders, and port authorities. Each business partner had a node on the chain.[75]

Sharing product data on the blockchain is key to establishing and tracking provenance; what data should be on- versus off-chain requires careful consideration

Tracing a food commodity digitally requires consistent data on the identity of the commodity as it passes through the supply chain. Often, there is no standard for a product's "identity," but many organizations have defined identifiers or specific data attributes that serve to identify the specific product. Provenance defines a food commodity on its blockchain by its nature, quality, quantity, and ownership.[76] BeefLedger defines its key data dimensions as product, period, place, people, and price.[77] In the example of Provenance, certification and license information was tracked to achieve proof of compliance at each step of the supply chain.[78]
As blockchain supply chain solutions are piloted, it is critical to consider what type of data should be on-chain versus off-chain given the permanence of blockchain,

and given that there are risks associated with data, for example, if bad actors know that there is a regularly shipment of high-valued commodities from A to B, they could intercept the supply chain and thereby causing significant damage to commodity prices, manipulating the market. Once the data is on-chain, it cannot be removed. Thus, organizations need to consider the unintended consequences and possible high-risk outcomes that could take place in the process of considering the technology.

Robust, reliable, and standardized data is best captured using data-capture technologies, such as Internet of Things (IoT), sensors, and smart tags

All food traceability blockchain solutions include the use of traceability technologies to digitize the identity of the food commodity and/or track changes to the product in real time. Information captured by a human can be subjective, unreliable, and/or susceptible to fraud, even among experts in the field. The use of sensors and IoT, for example, allows for the automated capture of consistent, reliable data as the product moves through the supply chain.

Many of the case studies reviewed leverage a smart tagging mechanism to identify either an individual product or box of products through the supply chain. With the scan of a QR code or RFID tag, data on the product can immediately be recorded at that location and time. Other uses of traceability technology include providing specific data on the product to add to the blockchain. For example, Belagricola leveraged IoT for measuring data on grains during storage and logistics. Soybean information, such as moisture level, was recorded automatically on the blockchain by IoT, allowing for grain classification to apply a batch digital quality seal.[79] Like Belagricola, WWF leveraged IoT and sensors to track the temperature of tuna through the supply chain for cold chain and quality assurance. Other uses include capturing the weight of the commodity and geolocation of a vessel.

Interoperability between the blockchain system and enterprise systems across diverse actors in the supply chain is critical; user experience should be considered at each level

For any digital solution to be adopted by every actor on the food supply chain, ease of use is essential to encourage adoption. For the fisherman, the warehouse manager, and/or other similar actors in the product ecosystem to use the technology, the technology must be of value. It needs to make their day-to-day lives easier, more efficient, and fit for purpose. Actors across the supply chain will need appropriate applications that serve their needs.

In Provenance's tuna pilot, a mobile solution was used to allow fishermen to register their catches. At the point of catch, a fisherman would send a simple SMS message to register their tuna catch. With each SMS, a new asset accompanied by a permanent, unique ID was issued on the blockchain. This unique digital ID would then be transferred from fisherman to supplier on the blockchain during purchase of the tuna product. At the processing facility or warehouse, Provenance integrates with an existing traceability and production software system, such as Tally-O. At the end of the supply chain, Provenance conducted a workshop and prototyping session to develop a smartphone application that allowed consumers at a UK grocery store to view the history of each product through the scan of an NFC-enabled smart sticker.[80]

Sensitive data on key actors and their food commodities should always be protected in an ecosystem that impacts global consumers and capital markets

Data shared on blockchain is tamper-evident and accessible to those that have the right permission to see it. Therefore, organizations that are building a blockchain-based solution should consider what type of data should be on-chain, what data need to be accessed by whom, for how long and for what purpose, and what data should be limited to one-to-one transactions. Blockchain supports access control concepts and can be very granular. For food commodities specifically, tracing a commodity can include sensitive data about actors and their products. A malicious actor with access to this information could impact consumers and capital markets.

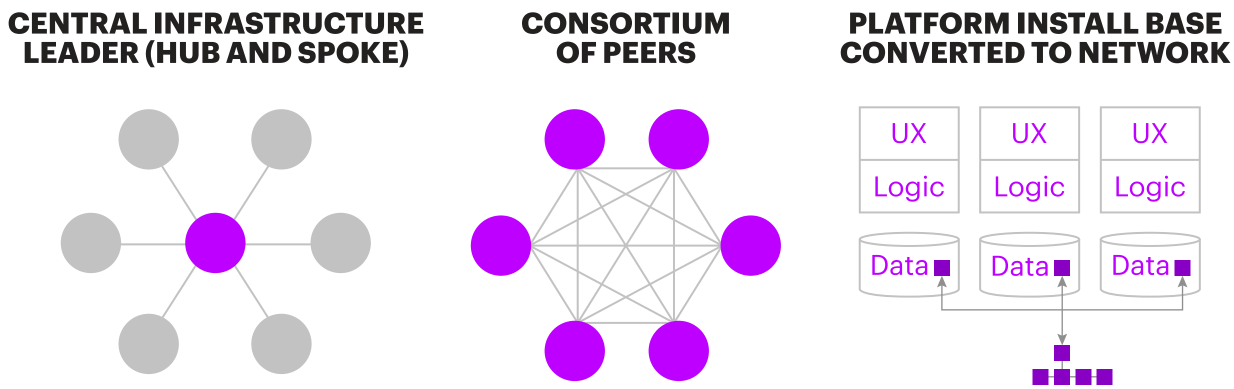
Both Belagricola[81] and Walmart[82] leveraged a permissioned Hyperledger Fabric blockchain platform to trace food quality and safety. Even with public blockchain platforms, a permission layer can be leveraged to provide the right users permissions to certain data. Most enterprises and governments will be deploying permissioned or private blockchain to apply appropriate business and risk rules, manage the ecosystem and network, apply the appropriate governance model, and protect the parties in the ecosystem, as well as protect the confidentiality between trusted parties. In the UK Bill of Lading proof of concept, Ethereum was used, which had specific security requirements in place to protect information.

A trusted, neutral third party that plays an audit or certification function would be beneficial to increase the level of trust of each participant and the data that they enter into the system

To improve the trustworthiness of the system and the confidence that the right pieces of information are gathered by trusted parties, there is a role for a neutral third party to certify, audit, and/or regulate participants. This role can vary based on the commodity and part of the supply chain being addressed. For example, to capture tuna catch data in Indonesia, Provenance leveraged local NGOs to register fishermen and validate their compliance to an external standard at the point of capture, which resulted in the fishermen's eligibility to participate in the Provenance chain of custody. The local NGOs had the audit systems, external standards information, and local networks in place to complete this assessment, and their existing technology capabilities allowed them to share the registration on the blockchain.[83]

Blockchain deployment patterns

Figure 11: The three most common deployment models for blockchain solutions

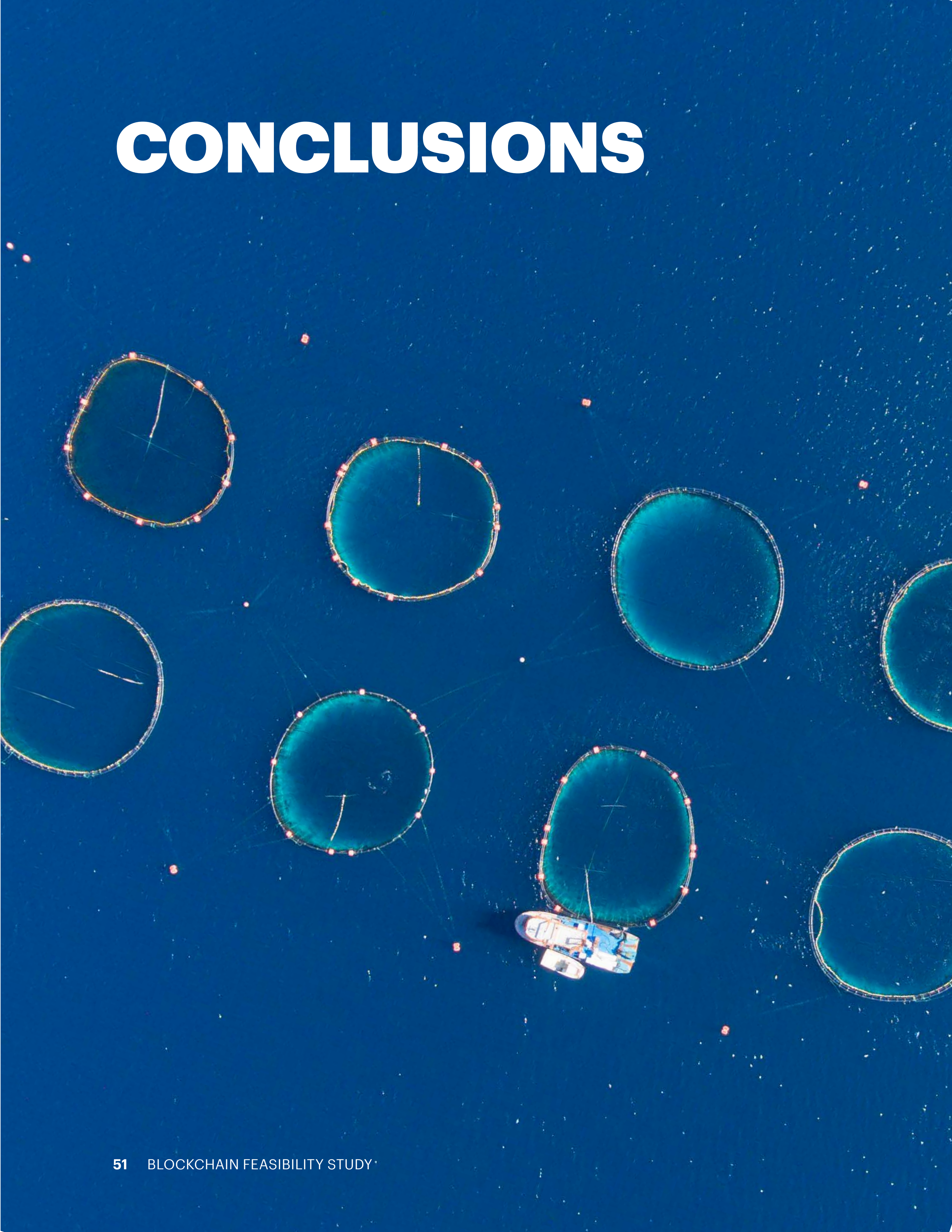


Blockchain solutions like those described above are being deployed in distinct ways. Coordination, strategy, governance, infrastructure, and the supporting ecosystem can be led through a central leader or consortium of partners, for example. In a market leader-centric, or "Hub and Spoke" model, a single entity would lead the effort of designing, implementing, and operating the blockchain supply chain system and get the rest of their supply chain partners to adopt and participate in the system. This is the model adopted in some of the initial supply chain pilots primarily led by a single large organization with several suppliers in their supply chain.

In a Consortium of Peers model, different stakeholders (governments, regulators, producers, processors, suppliers, NGOs, etc.) agree to form a consortium to build and operate a blockchain supply chain system that they all use. Each participant would have their own incentive to participate. This model is more complex in governance and adoption than the Hub and Spoke model, but the outcome is also transformational as it considers a wider ecosystem of stakeholders vertically and horizontally.

In a model where a platform install base is converted to network, existing organizations that already must communicate with each other, with data going back and forth between each other, would benefit by connecting through a blockchain network; this increases efficiency significantly as it reduces the need to validate and reconciliate data between the parties.

CONCLUSIONS



Blockchain makes it possible for a system of independent actors to share and trust a record of digital assets, transactions, and information. In doing so, it offers the potential to disrupt and transform existing business models.

A growing number of successful pilots show how blockchain can provide the network for registering, verifying, and tracking goods transferred between distant, and often mistrustful, parties connected via a supply chain. It can also improve operational inefficiencies, reduce fraud, and even alleviate humanitarian challenges, such as exploitative labor practices and environmental degradation, by enabling greater certainty, transparency, and accountability on the information shared between parties.

Blockchain should be evaluated against other technologies with a specific use case to quantify benefits and costs.

For all four of the commodities, farms are, by nature, geographically dispersed and decentralized at the base of the supply chain. Initial information input at this level needs to be supported by technology and processes that allows for decentralization. Blockchain is a good fit for this and has the potential to deliver cost savings (e.g., reduced data reconciliation or faster recalls) and efficiency gains (e.g., reduction in duplicative processes and paper-based documents). Using a blockchain-based system could improve the speed at which data can be collected from diverse locations.

To reap the full benefit that blockchain could bring, there needs to be a degree of digital capabilities across the supply chain, the availability and willingness to implement traceability applications that can be integrated with blockchain, and basic connectivity to help the base of the supply chain in remote locations to close the digital divide. A well-defined use case can help businesses determine if blockchain is the right path by testing what value it can unlock.

Blockchain technology and business use cases for supply chain are growing rapidly. Those considering these solutions should be involved in the evolution of the technology and its applications. Blockchain offers a variety of market actors the opportunity to become better environmental stewards, in large part because of its promise to enable greater transparency, trust, and accountability. Blockchain platforms are still being developed and refined, and its potential is still being discovered. Early adopters can shape the way the technology advances by applying it in new ways, addressing new issues, and supporting a variety of different actors.

Some use cases should be prioritized based on business value while others require additional business incentives to be financially viable.

Current food supply chains vary in their complexity, regulatory environment, and market incentives, so blockchain may not be feasible across all food commodities in the near term. Therefore, defining the use case is critical to establishing success metrics. For example, a use case with environmental sustainability as a goal may have a different design and implementation path than a use case focused on food safety and recall time.

The level of effort and transformation required to implement the pilot should be carefully considered and evaluated against the value that it brings and the feasibility criteria. Food commodity supply chains with reliable and trackable product identity, as well as those that align to business and regulatory incentives (e.g., ability to trace a food contamination outbreak quickly to the source), may provide an easier starting point as less up-front transformation work may be required. Additionally, while investing in blockchain for higher-value products may be a key place to start, there may be a strong business case for investing in blockchain for lesser-value products when the overall goal is to gain or regain brand trust, when recalls have been frequent or costly or where efficiencies gained could make a substantial impact on profit margins.

It would be more difficult to deploy blockchain capabilities in the near term for specific food supply chains where little value is expected from blockchain; some of these include supply chains that are highly disparate, with little standardization of data, operate in highly complex markets, or lack clear financial incentives, regulatory incentives (e.g., using a blockchain traceability system to comply with regulations in a more efficient way), and/or limited potential product premiums. To unlock the full value and to motivate companies to invest and adopt a blockchain, the system needs to accommodate different commodities and should support multi-ingredient packaged foods across an entire supply chain.

When a blockchain-based traceability system for the full end-to-end supply chain for a given food commodity is not feasible, a minimum viable product should be prioritized.

In certain cases, an end-to-end blockchain system with full coverage of the entire supply chain may not be feasible. However, organizations can still realize the advantages of blockchain traceability for a portion of the supply chain where the impact and/or commercial benefit justifies the investment. Most successful pilots choose to start in a selected segment of a given supply chain; few would attempt to do this end-to-end.

It is far more realistic and practical to start at a specific point in the supply chain that already has some digital capabilities, where there are multiple parties requiring a consistent set of data attributes for their own operations and where operations and financial incentives are well aligned to transform the existing process by eliminating inefficiencies through blockchain. This minimum viable product can then be prioritized and should be considered as a starting point. Focus on what can be agreed on between the parties and who the right parties are, and evaluate whether there are sufficient business gains made, prior to increasing participation or building out a full consortium.

To implement a blockchain traceability system, a degree of digital transformation is required; thus, a significant amount of up-front effort across commodity supply chains is required to achieve sufficient integration and interfacing as well as the proper market incentives.

A significant portion, if not majority, of the effort will center on governance setup and implementation as well as the digital transformation that would be required for the user/customer experience. The effort required to pilot and scale a blockchain solution could include vertically integrating and setting up preferred supplier relationships within the supply chain, developing collaborative relationships and governance approaches that consider the needs of all actors, and digitally transforming key actors to bring technology infrastructure to a baseline level that allows participation and compliance. Significant change management and capacity building may also be required, particularly for actors who are less familiar with the technology.

Supply chain actors may need to invest in closing the digital divide to participate.

Without the proper incentives and support, some actors will not be able to participate. To fully realize the benefits of blockchain and ensure widespread adoption, additional enabling technologies may be required to help ease reliable data input, such as smartphones, tablets, scanners, sensors and geospatial technologies, and electronic payment systems. The cost of participation may be prohibitive to key actors who will require additional investment, support, and incentives. However, this could also be a catalyst to help close the digital divide in rural populations and developing countries.

The successful application of blockchain requires strong planning, mobilization, and coordination.

It also needs a comprehensive technical and functional strategy that works for a broad set of actors in the supply chain and a strong supporting ecosystem. Blockchain both enables and requires a new way for businesses to work together. To achieve the business benefits, organizations along the supply chain need to collaborate to become more of a platform economy. The functional and technical strategy serves as a "North Star" for the consortium and their technology partner(s). To be successful and widely adopted, the investment and processes for adoption of blockchain traceability solutions require a supportive market and regulatory ecosystem.

It is not necessary for all supply chain data to be accessible across all actors. Actors should agree on a data model that can share required traceability data and protect sensitive product data on the blockchain.

Food supply chain data can be sensitive. Breaches to data security can impact global markets and the broader consumer population, as well as de-incentivize actors to join a blockchain traceability solution. Thus, actors involved in the blockchain solution should only share data that is required to enable product traceability across the end-to-end supply chain and leverage layers of permissions to only allow certain parties to access certain product data.

Private, public, and hybrid blockchain solutions each have unique strengths and weaknesses depending on specific requirements. It is not necessary to build applications on a public blockchain to reap the benefits of transparency and accountability.

The decision to go with a certain type of blockchain depends on the organizations that are participating, objective of the group, the types of data to be shared, transactions that will take place, business rules and policies, risk appetite of the organizations, performance and security requirements, and numerous other factors.

For example, enterprises and organizations use private, permissioned blockchain for greater control on who they choose to work with and who participates in the network, what types of policies and rules need to be implemented, privacy and data confidentiality, and which types of capabilities that are required for their needs. What data the consumers and the public see would require an application and user interfaces that are built specifically for the end users to have access to the appropriate information, such as product origin. The blockchain itself is a network of data that requires translating into meaningful information for the end user. With private, permissioned blockchain systems, there is the need for governance between participating organizations; this is true even if public blockchain is used as a platform among a group of organizations. A consortium should first design the business case and requirements and then focus on selecting a platform that is best suited to meet the need.

A solution design with the minimum amount of negative disruption to the current supply chain is recommended to increase blockchain adoption in the near term.

To encourage users to adopt a blockchain system, the system needs to provide value. Processes need to emulate what they are today but be more efficient, easier to use, faster, and cheaper for users to rapidly adopt the system. It needs to be intuitive and require minimal amount of user training. In the food commodity supply chains of interest, a significant level of effort is required to digitize and standardize product data and allow actors to transmit reliable data; in fact, this is true for any digital agriculture supply chain transformation and not just limited to blockchain. The focus on blockchain may increase the speed of change at the base of the supply chain as large enterprises at the top of the chain have a greater need for transparency of information, greater efficiency, and cost reduction, as well as greater need for improving their reputation and "green credentials" to their consumers and shareholders. The digital transformation required could help to close the digital divide, but the user experience for each type of user across the supply chain must be considered.

A blockchain traceability solution should consider the implications of cross-platform interoperability.

Interoperability is key to ensuring the data consistency across the ecosystem and its integration with the systems and solutions of other actors. Both technical interoperability and functional interoperability should be considered when designing the blockchain solution. It is likely that there will be several different blockchain supply chain solutions in the market and they might be incompatible from a platform perspective, for example, one system uses Hyperledger Fabric and another application uses Hyperledger Sawtooth.

Today, there are multiple blockchain platforms used, but none have emerged as a clear winner for supply chain. Organizations will encounter layered costs just as they do with multiple "traceability" software vendors. Organizations need to ensure there is flexibility built into their application architecture to enable applications to operate across different platforms in the future.

There is a vital role for anchor businesses and regulators to take a lead in the adoption of blockchain traceability solutions and multi-stakeholder collaboration.

To move beyond trust-dependent and self-reporting approaches to traceability toward trust-independent transparency and accountability in the market, downstream businesses and regulators ought to take the lead in coordinating blockchain traceability solutions. If these are to succeed, they will require appropriate regulatory, market, and financial incentives. These incentives can be achieved with innovation, willingness to collaborate, leadership commitment to a shared vision, and coordination from organizations with the ability to convene and facilitate broad participation from the top of the supply chain to its base.

Developing a blockchain solution should be incremental and iterative.

The end-state solution does not need to be realized immediately, and actors should take an agile approach to test, refine, and roll out a solution through a proof of concept, a limited production pilot, and production and scaling. A blockchain solution for a food supply chain will take time to fully develop. Achieving the proper buy-in and realizing benefits across actors will require an incremental and iterative approach to a solution design.

Actors should aim to start small and start "somewhere" and prove business benefits, assessing and re-assessing the blockchain solution at each point. Actors should take the successes to key ecosystem partners to grow the consortium and encourage participation. In this way, the investment will increase incrementally at each step, and actors can decide to close or continue the initiative with minimal risk.

In addition to core business drivers and financial measures of success, blockchain has potential to drive impact in social good use cases, such as environmental sustainability.

By revolutionizing how organizations manage and share information as well as extract insights, new models begin to emerge for promoting responsible and sustainable practices for food commodities. Examples include the ways that actors perform, compete, and draw value from commodities and public goods. New measures for business performance may also be introduced, redefining what it means to be a green and sustainable company. Likewise, consumers need to be able to have access to information to influence how food commodities are traded, produced, and sold, and consumers want organizations to be held accountable for the decisions they make. The rule book for blockchain supply chain systems has yet to be defined and this is an opportunity for organizations to influence and collaborate to build a shared vision. As organizations experiment and continue to bring to market successful projects, the trend is here to stay.

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