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Traceability of Agricultural Supply Chains in Latin America using Blockchain: Guidelines to implement traceability of Avocados in Columbia

Authors: Priya Sampath (MIT) and Rohit Sharma (MIT)

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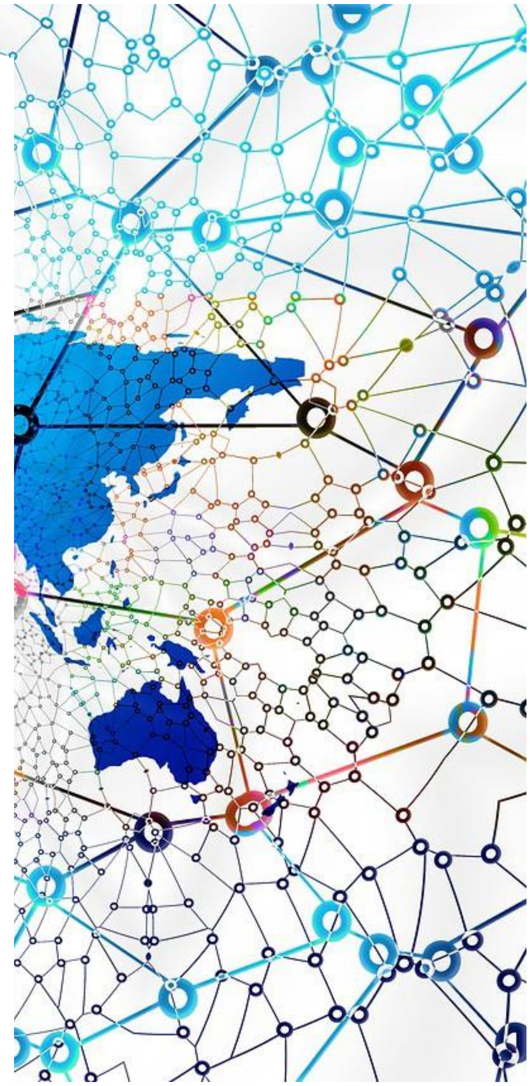
Guidelines to implement traceability of Avocados in Colombia



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15.S68 MIT Blockchain Lab

Authored by: Priya Sampath & Rohit Sharma
Advised by: Michael Casey

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Executive Summary

The project – Traceability of Agricultural Products in Latin America – was commenced by Inter-American Development Bank (IDB) to evaluate the potential of blockchain technology in improving the traceability of agricultural produce in Latin America, with an aim of reducing the waste that is generated at different points in the supply chain.

As part of the project, we first started looking into the applicability of blockchain as a traceability solution. Our aim was to determine if the technical complexity of blockchain solutions make them too complex for a use case such as traceability. After reviewing a host of literature on the usage of blockchain in supply chain systems and evaluating few real life blockchain-traceability prototypes, we arrived at the conclusion that blockchain as a transparent, immutable and distributed database can be a good tool for improving traceability across food supply chains.

Once we established the case for blockchain as a potential traceability solution, and explored the use case – avocado supply chain in Colombia. This is an extremely scattered, low tech, low trust, complex supply chain with many actors that presents unique challenges for traceability. While we were not able to discover data about food waste and loss at various points of the supply chain, we were able to come up with criteria to identify traceability targets in this supply chain. We suggested warehouses as the starting point, as they are often the first instance of formality in a fragmented supply chain.

Next we created a framework to help IDB think about how they implement the solutions on ground, and the pre-requisites and conditions they need to account for, before implementing a solution. This exercise of looking deeply into a value chain and applying blockchain for traceability helped us unearth some insights that should give IDB some food for thought:

- The total loss across a food supply chain can be segregated into loss & waste. Loss is mainly at the producers end, caused by factors such as poor quality or production techniques, whereas waste is due to factors such as transportation, poor storage facilities, long time spent at warehouses etc. IDB needs to identify which area they would like to focus on.
- A popular perception about block chain is that unless every stakeholder provides data, a blockchain is not a viable solution. This is not true. The process can be started with even one stakeholder putting data in the system, and then pushing actors upstream and downstream to do the same.
- Blockchain cannot ensure the quality of the data entered into the system. A garbage data input would result into a garbage data output. However, even a garbage data collected over time can give insights into the process.
- IDB will be well-served by applying a 5-pronged framework that came out of a conversation with IBM's Food safety team - *Business Value Proposition, Ecosystem, Governance Policy, Standards and Technology.*

Recommendations

IDB would be well-served by thinking about the following 5 points framework, before planning to implement a blockchain based traceability solution:

1. **Technology**: Start by using an existing solution rather than developing an indigenous solution – there are many open-source and commercial options that can serve as a base for the pilot, then adapted for larger implementation.
2. **Business Value Proposition**: IDB has no direct authority over supply chain actors – this requires IDB to think through the incentives they need to create in order to encourage different parties to share their data on the system. One interesting feature supported by blockchain technology is Smart Contracts – contracts that reside on blockchain and are automatically executed when certain conditions are fulfilled, and these smart contracts at the traceability targets can be programmed to release incentives for compliance by different supply chain actors. The incentives should include both one-time and temporal / longitudinal performance measures.
3. **Ecosystem:** As there is a paucity of quantifiable data from the different value chain actors, the traceability effort should target that point in the supply chain which is at the first instance of formality – in this case, we suggest warehouses. Once the warehouses become a part of the system, they can start pushing the next level of actors both upstream and downstream to be a part of the system.
4. **Governance Policy:** To match the needs of the participating ecosystem, designate and develop rules for access and rewards for participation.
5. **Standards**: Uniform data, technology and supply chain standards. For example, most supply chains conform to GS1 standards. This may be an aspirational goal for this project.

Ultimately, the success of such an effort will result from IDB's ability to design and implement a collective action in which disparate actors are incentivized to change their interactions and will accrue benefits as a result of this change.

A popular perception about block chain is that unless every stakeholder provides data, a blockchain is not a viable solution. This is not true. While Blockchain cannot ensure the integrity of the data, any data is better than no data in this situation. Incentives can help.

1. Introduction

Blockchain Lab is a project-based course at MIT's Sloan School of Management, in partnership with the Digital Currency Initiative, (DCI) at MIT's Media Lab. It is designed to involve students in the latest developments as companies research and prototype blockchain technology – and attempt to integrate it into viable business models[1]. This is the inaugural class of this subject. Teams of students with a mix of skills worked with DCI "member companies" on hand-picked projects that ranged from prototyping to developing business models around existing applications of blockchain technology.

The Inter-American Development Bank, ("IDB" or "the Bank") established in 1959, is the main source of financing for economic, social and institutional development in Latin America and the Caribbean (LAC). It provides loans, grants, guarantees, policy advice and technical assistance to the public and private sectors of its borrowing countries (www.iadb.org). Among its activities, IDB is supporting LAC countries towards reducing food waste through enhanced supply chain performance.

Much has already been written about blockchain technology and its potential to disrupt many aspects of finance, commerce and government operations. For an introduction on the technology, we point you to MIT Technology Review and their blockchain primer[2] which provides a comprehensive explanation of the basics of the technology.

One of the more promising and active areas for the application of blockchain technology is supply chain management. The many features of supply chains – multiple actors at every stage, typically a low-trust environment, lack of all-party visibility, need for agreement on terms by multiple parties, need of tracking goods as they make their way from source to final destination, and the inefficiency and complexity of current systems, make it an attractive field in which to experiment with improvements – and applications based on blockchain technology are often seen as promising. The immediate, immutable, distributed and transparent nature of blockchains is a feature that most legacy systems have been unable to duplicate. Considering the complexity of modern supply chains and the associated costs in the multi-party structure, and with reducing cost of data storage and computing/processing, the incremental benefit of blockchain has the potential to exceed the cost.

The immediate, immutable, distributed and transparent nature of blockchains is a feature that most legacy systems have been unable to duplicate.

[1] 15.S68 Course description in Syllabus, from Course website.

[2] MIT Technology Review

Given this promise of immediacy, trust and transparency, provided by blockchain, IDB's interest was to explore if enhanced traceability through blockchain technology could help reduce the amount of food lost every year as a result of lack of transparency, trust and enforcement in agricultural supply chains – an issue of concern in Latin America, where every year 15 percent of annual production is lost, 74 percent of which is due to inefficiencies in production and logistics processes[3]. Would a blockchain solution provide enough visibility into the movement of agricultural products, to enable interventions to reduce waste? This is illustrated in the Figure below:

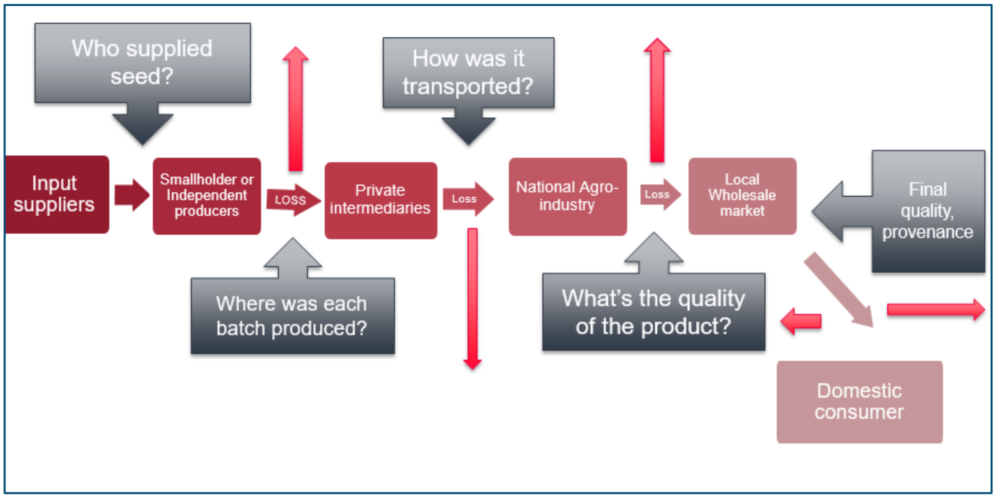

Figure 1: Losses in a hypothetical supply chain and potential questions

[3] FAO, 2012

2. Project Problem and Scope

The original problem set up by IDB in the context of food waste and loss in LAC was to design a pilot to test the potential of blockchain technology to improve the traceability of agricultural products in a supply chain.

The initial project scope included the following activities: (i) supply chain selection and mapping; (ii) identification of traceability targets vis à vis potential waste risks in supply chain processes; (iii) design of a blockchain technology architecture to ensure traceability across the supply chain; (iv) toolkit for pilot implementation using blockchain technology to improve food traceability across the supply chain and analyzing the potential of the information generated by the technology to be used in smart contracts.

2.1 Changes in scope: Use existing technology

An initial survey of the technological landscape revealed quickly that there were several open-source and off-the shelf options available, described in Chapter 3, which could be employed for IDB's purposes. Therefore there was little added value in the team utilizing its time to develop yet another solution – especially without further details about the types of information that was available about specific supply chains. While blockchain supply chain solutions are in general supposed to be supply chain agnostic, given the big-picture mandate of the project and the wide variations in operating conditions across LAC mean that the choice of the solution could potentially be informed by the context.

2.2 Redefining scope: Choice of Supply Chain

The project mandate, to test the potential of blockchain technology to improve the traceability of agricultural products in a supply chain, was very broad, and needed to be narrowed down to a specific supply chain. Given the nature and duration of the project, the choice of a case study was limited to a perishable supply chain that was already mapped out, with data related to the movement of commodities from one point to another, and description of actors.

Perishable supply chain was a criteria given the ultimate aim of the study – to understand loss and waste in agricultural supply chains. This was a decision guided by the Bank representatives.

Mapped out, because the mapping of a supply chain can be a project in itself, this was ruled out by the duration of the project.

With data, as the identification of traceability targets vis à vis potential waste risks in supply chain processes (the second activity in the original scope) required an informed decision to be made in the context of the current state of affairs related to waste. Without knowledge of points of waste and loss in the supply chain it would be impossible to target points of interventions or application of the technology. End to end application of a supply chain blockchain solution would be extremely impractical given the macro perspective of the problem.

Description of entities at each step of the supply chain is needed in order to understand which entities would have to participate in the traceability solution and also, which information would be required from them.

The effort to find a mapped out supply chain took up a considerable amount of the project time as the IDB team and the MIT students attempted to source a mapped out supply chain and associated data on the movement of goods. Ultimately a recent study that studied the avocado supply chain in Colombia[4] was used. Based on the above, the final scope of the project was to develop a toolkit for pilot implementation using blockchain technology to improve food traceability across the avocado supply chain in Colombia, and analyzing the potential of the information generated by the technology to be used in smart contracts.

[4] University of Colombia, 20018

3. Research Findings

The research finding speak to the state of blockchain supply chain applications, early innovations and pilots by companies using blockchain for supply chain management, and specifics of the supply chain itself.

3.1 Overview of Current Blockchain Solutions

The table below gives an overview of few of the currently available blockchain based traceability solutions. While some of these solutions use traceability for tracing the origin and journey of food products (provenance), others use traceability to ensure food safety or transparency across the product value chain. Of the few shown below, some were developed for a specific use case, (Wageningen University), and some for commercial application (IBM, Citizen Reserve, and Sourcemap). Having said that, the usage of blockchain for traceability is a fairly new use case, and only few of these have been extensively tested on real life supply chains.

Product	Base	Focus	Stage/ Clients
Open Source solutions			
B-verify	Bitcoin Blockchain	Issuing and transacting in verifiable records	Pilot underway
Wageningen University	Hyperledger Fabric	Certification & Provenance	Demo Use Case
Proprietary / Commercial Solutions and clients			
Citizen's Reserve	Ethereum Public (ERC20) + Quorum	Supply Chain as a service platform	Industry Partners not public
IBM's Food Trust Initiative	Hyperledger	Food safety, Provenance	Walmart
Tracr	Ethereum	Diamond supply chain	De Beers
Provenance.org	Ethereum	Transparency	In operation
Microsoft Azure	Ethereum/Corda/ Hyperledger Fabric	Blockchain as a service	Starbucks
SAP blockchain Solutions	Quorum/Multichain/ Hyperledger Fabric	Blockchain as a service	BumbleBee Foods

Table 1: Existing Supply Chain Solutions Using Blockchain

3.2 Blockchain in Supply Chain Use Cases

3.2.1 Solvay – Sustainable Guar Initiative

In 2015, Solvay and its partners L'Oréal and Henkel launched the Sustainable Guar Initiative to support the livelihood of guar farmers in Northwestern India. Guar is a legume whose seeds are used as a gelling and thickening agent in many products such as personal care. Solvay transforms guar and sells it to manufacturers. For the

Initiative, they needed a system where the origin of the product could be fully guaranteed. The chain of guar production is long and complex, with many intermediaries, which makes it difficult to precisely trace each bag of seeds. So Solvay built a private blockchain for all the stakeholders throughout the guar value chain, from the farmers to the plant that transforms the seeds into powder, the shipping to the US and finally to the factory in Texas. All actors in the chain will be required to record their transactions in it. After a trial early 2018, the blockchain is now ready to be implemented. The farmers will use a smartphone app to enter the exact amount of guar they sold, and at what price. This will create a specific ID for each bag that will follow the guar all along the way, connecting every single kilo of seeds to any single kilo of end product Solvay sells to its customers.

3.2.2 IBM – Food safety Initiative

This product entered the public consciousness via a pilot with Walmart. Food origin and traceability is costly fir grocery chains and food companies and leads to considerable food waste. In addition, 420,000 people die each year due to food poisoning. IBM Food Trust combines blockchain, along with IoT technology, such as sensors and RFID tags, to enable real-time data to be written on blockchain as food products pass along the supply chain. Current implementation included Farm to fork program at Unilever,

3.2.3 Waaginengen University

Wageningen University, Netherlands was a part of a (PPP) project 'Blockchain for Agrifood' in Netherlands in early 2017. The main goal of the project was to understand the implications of blockchain technology on supply chains. As part of the project, a proof of concept application was built for a table grape supply chain, for grapes imported from South Africa. The proof of concept consists of a blockchain based system that keeps track of certifications applicable across the supply chain. Wageningen later published the code they used for this proof of concept, on Github[5].

3.2.4 Tracr – DeBeers

Tracr platform for De Beers seeks to bring greater traceability to the Diamond supply chain to address the issue of imposters and conflict minerals. A pilot was created for a selection of rough diamonds mined by De Beers as they moved from the mine to cutter and polisher, then through to a jeweler. De Beers has not decided on the cost of joining Tracr but is working on minimizing costs for smaller players

3.2.5 b-verify

Developed by MIT – DCI (Digital Currency Initiative), b-verify is a new protocol on the bitcoin blockchain for issuing and transacting in verifiable records using a public blockchain. The first use case of the protocol – negotiable warehouse receipt for agricultural commodities – is underway. Once the first use case is successfully implemented, the protocol can be developed to handle other transactions across the supply chains.

[5] https://github.com/JaccoSpek/agrifood-blockchain

3.3 Characteristics of Selected Supply Chain – Avocados in Colombia

As described earlier in the report, the selection of an appropriately mapped out supply chain with some data was the most challenging part of the project. However IDB was able to identify two studies[6] that had mapped out avocado supply chain in Colombia, and also, crucially, some information related to losses[7].

According to the reports, in Colombia there has been a marked growth in the area sown and production of Avocado, due to the wide availability of areas suitable for cultivation, the product prices and unsatisfied demand of this fruit in international markets. Due to the demand for avocado and the high potential profit, great effort is being made in the country to improve the productivity and competitiveness of the avocado crop. Many government organizations are supporting the growth of the chain.

The commercialization of the product from the small and medium producers of avocado in the country, occurs, generally, through the big producers, who act as intermediaries when buying the production obtained from the harvests by offering credits to the farmers, with which they assure the sale of the producers realizing the "purchase in the tree"[8].

The packaging used to sell avocados is made in sacks or sacks of approximately 100 units, no boxes or any other kind of packaging are used. The fruit is transported from the production areas to the municipal headwaters in campers, without any care that prevents bruises or mistreatments that diminish the quality of the product; the bags are arranged in the upper part of the field and from there, through roads in poor condition, is transported to the collection center of the municipality.[9]

The high-level view of the Avocado supply chain in one region of Colombia is below[10].

[6] Project report "Productivity and Andean Fruit Competitiveness" developed by the National University of Colombia.
[7] Becerra, César, Cárdenas, Andrés, Gutiérrez , Diego F. Fina Report: Study to reduce first-mile food loss in agricultural chains - LOGYCA/RESEARCH December, 2018.
[8] Castilla A. & Hernandez D., 2009
[9] Ibid
[10] Project report "Productivity and Andean Fruit Competitiveness" developed by the National University of Colombia.

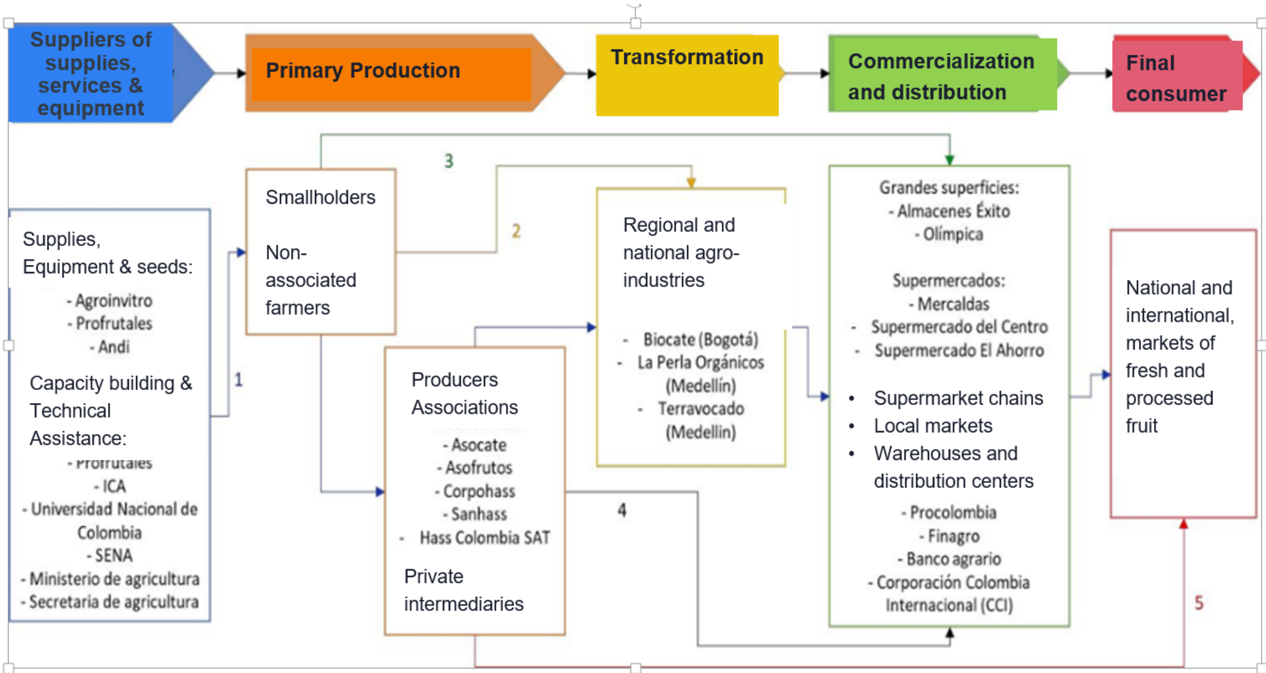

Figure 2: Avocado Supply Chain in Colombia.
Source: "Productivity and Andean Fruit Competitiveness" National University of Colombia.

The features of this supply chain are:

- *Multiple distribution channels*: based on the map, there are at least five distribution channels involving multiple actors.
- *Fragmented:* Actors are spread across vast geographies: necessitating transportation at every step. The fruits are transported in trucks without any type of conditioning or refrigeration (room temperature), without considering the minimum technique of transporting perishable products, which causes large losses of product.
- *Multi-layer:* There are often multiple entities at every step, due to the widespread geography of this value chain and the many layers of aggregation before the product gets to the final consumer. Nearly 50% of the avocado produced in the country is marketed to intermediaries, who are mostly large producers.
- *Low levels of technical capability and usage:* Most operations, especially upstream in the value chain, are in remote areas, and fairly basic, sometimes even without cellphone connection.
- *Growing presence of large national and international buyers*: Colombia has seen a growth in exports of fresh and processed avocados, which means there is increasing formalization on the downstream side of the supply chain.
- *Informal record-keeping:* Many of the upstream entities are small scale producers and actors that keep mental or paper versions of records.
- *Low levels of trust, opaque environment:* Many relationships are transaction-based and there is low level of trust as each actor tries to maximize their profit.

Due to these reasons, it will be extremely challenging to implement an end-to-end traceability solution, even within one region. The shortest delivery channels or supply chains in this context are the exporters' supply chains, but they are a small (but growing) proportion of the overall ecosystem. However, if there is an exporter willing to cooperate with a pilot traceability effort that may be an easy approach to piloting a traceability software. However, the pattern of losses in this supply chain will be considerable different from those in other delivery channels due to the stricter requirements and more formal and sophisticated nature of these supply chains.

3.4 Traceability Targets

The project team's first approach was to identify targets based on loss and waste patterns. The data-driven approach was based on the hypothesis that the most likely target for traceability would be the section of the supply chain where most of the loss and waste was occurring. The underlying assumption was that since there would be costs to traceability and the ultimate motivation in this case is to address the issue of food loss and waste, finding the "leakiest" section would have the maximum payoff.

However, finding data at this level of granularity turned out to be elusive. Interviews with logistics and supply chain experts at MIT and around the world, revealed that this was a prevalent issue; it is practically impossible to find aggregate level data across each step in the supply chain. However, the Logyca report[11] added one piece to data that narrowed the prospective targets: the report concluded that at least for the farmers they interviewed, the majority of the losses did not happen in the first mile, i.e. it was not associated with on-farm production and harvest. A significant amount of produce (up to 68%) was "rejected" due to appearance and quality at the production stage for producers that who were selling to exporters – however the rejects were still put to productive use and hence cannot be strictly counted as loss[12]. Therefore the implementation target would have to be further downstream.

In addition, a representative of a firm that has developed a proprietary supply chain product, R3[13], exhorted us to focus on changing the user experience, with actors that can take on change, implying that the chances of success of a pilot traceability effort or proof-of concept would be greater if we started with supply chain actors that we already using technology in some fashion.

3.4.1 Key Assumptions

There is an inherent assumption that unless every stakeholder provides data, a blockbhain solution is not viable – meaning blockchain applications would only be successful if all participants and providers updated information reliably. However, given the low application and awareness to technology, such a high standard would limit the success of any traceability effort at the outset. In

[11] Logyca, 2018
[12] Ibid
[13] Conversation with Alisa DiCaprio, R3

the current scenario, any data would be better than NO data – upto a point. The central question at this point was - where are there trust and technology issues in this supply chain enough of an issue to pilot or test a solution, but where the technology adoption curve is not so steep that it will stymie it? What does such a point look like? To identify such a point that would serve as a traceability target, the team then focused on identified a key point or points in the Supply Chain (after the 1st mile) that met the following criteria:

- The movement of avocados could be traced at least up one step and down one step to gain insight into losses.
- Currently has a somewhat formal system of record keeping so would not be daunted by a more technical "upgrade".
- An incentive structure could be "imposed" or "required" for data entry and recording.
- Multiple actors are involved.
- Exerts "pressure" upstream and downstream of the supply chain.

"Where (in this supply chain) are there trust and technology issues enough to pilot or test a solution, not so much that they will stymie it?"

3.4.2 Warehouses

The quest for the section or point of the supply chain that met the above criteria was informed by interviews with MIT professor Chris Meijia[14], and the Logyca research team, who are all extremely conversant of the situation on the ground in Colombia, and the Avocado supply chain.

The suggestion from Professor Meijia, and verified by the Logyca researchers, was to focus on warehouses and distribution centers. This was because they represented "fuzzy in, fuzzy out, and resolution within" – meaning the data process upstream and downstream from warehouses and distribution centers got fuzzy however there were formal records of goods received, stored and dispatched. In addition, many of the distribution channels include warehouses. They are usual legal entities - public, private or cooperative, therefore can be willing partners for IDB;

They are often the first link in the chain that keeps records, operating at the nexus of the formal and informal. The record keeping can account for multiple variables as they serve a variety of roles –cold storage, export import storage, distribution centers, for different types of commodities, and at different locations around the country.

3.4.3 Incentives

Unlike a giant buyer like Dole or Walmart that can impose requirement on its suppliers, IDB has no direct authority over supply chain actors. Given this reality, it will need to think about how to design a system of incentives to encourage supply chain entities to adopt a traceability solution.

[14] Interview with Christopher Mejía Argueta, April 2019 and Logyca team, April 2019

An incentive structure is necessary in order encourage a change in status quo – especially one that might call for changing behavior and bring greater transparency. In general, the supply chain participants will be more inclined to participate if, in addition to incentivizing participation itself, there is a promise of new opportunity for revenue rather than simply replicating current process via another mechanism[15]. Such a change requires a kind of collective action in which there is benefit if everybody participates and everyone is rewarded not just for participation, but also for the improved performance that ensues.

IDB is uniquely situated to created this incentive mechanism. As DCI advisory Michael Casey states when writing about International Financial Institutions, "*Having neither taxation nor profit-seeking capacity…..they do retain enough clout to influence certain governments and with which they could foment the kind of policy environment that cryptocurrencies and blockchain technology need*."[16]

In general, the supply chain participants will be more inclined to participate if, in addition to incentivizing participation itself, there is a promise of new opportunity for revenue rather than simply replicating current process via another, newer, more cumbersome mechanism.

Table 2 below illustrates some of targets of incentivization and how far down IDB can reach – in general, the more formal the supply chain actor, the more directly they can be incentivized. This is another reason to start the initial pilot with the a actor that meets a certain "formality" threshold.

	Incentive Target	Mechanism
Degree of formality ↓	The Government	Make lending conditional (include in new or current lending instrument)
	The Exporters	Govt can require additional traceability - Use Smart Contracts
	The Warehouse operators	Payout for enhanced performance using technology upgrade – Use Smart Contracts
	The Transporters	Will be hard to convince to participate unless immediate clear payoff is visible - Will need to see not just added cost but new / more revenue.
	The Producers	Smaller producers will be harder to target, the learning curve with technology is too steep. Larger producers or

[15] Interview with Alisa DiCaprio, R3 March 2019
[16] Casey, Michael 2017

		cooperatives and associations will need to see not just added cost but new / more revenue.

Table 2: Supply Chain actors and Incentives

3.4.4 Smart Contracts

In this scenario the use of smart contracts may prove to be the appropriate solution. Smart contracts are contracts between buyers and sellers, written as code into the blockchain. These are self-executing contracts, which execute themselves according to the coded terms, when a triggering event is hit.

Blockchain's ability to execute contracts automatically provides multiple benefits for a case such as traceability:

1. Buyers and Sellers, who are a part of the traceability system, do not need third party support to execute their transaction. The conditions for the transactions can be coded on the blockchain, and the code gets executed as soon as the transaction is over.
2. Incentives for different activities can be coded as smart contracts. For instance, as soon as a party enters data on the chain, the corresponding incentives get executed.
3. IDB can monitor the executed contracts over a period of time and can gain important insights such as movement of goods or movement of prices from a particular party. Such a time series data can prove to be highly valuable for a socially responsible organization such as IDB.

4. Recommendations

The research undertaken for the project shows that for IDB's needs, there are plenty of technical solutions that can be utilized. However, the Achilles heel of many technology implementations, and why many new technology solutions fail to find traction, is because not enough attention is paid to the context within which the technology is implemented, and the "softer side" of implementation is not factored in adequately. We recommend that IDB will be well-served by applying a 5-pronged implementation framework (see Figure 3) to an initial traceability pilot at a few select warehouses and then apply the lessons learned to tweak both the technology itself, and the incentives. To implement a

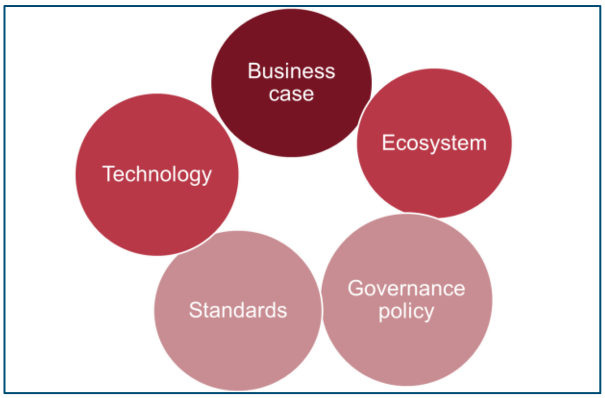

Figure 3: The Implementation Pentagon

Technology: Our research showed that there are many technology solutions currently available in the market, both open-source and by identifying an existing proprietary. Most notable among them being the IBM food trust initiative, in which companies such as Walmart are partnering with them to create a traceability solution using blockchain. Since, solutions are available, IDB's interest won't be well served by inventing a new solution. IDB would do well to pick a solution for a pilot program, and based on the results and its specific requirements, IDB might think about going for a proprietary solution.

Business Value Proposition: IDB has no direct authority over supply chain actors – they need to address the issue of how to incentivize the Supply chain actors to participate in the traceability solution. Given the fact that most of the actors in the avocado value chain that we focused on are informal actors such as small farmers or transporters, IDB need to spend a lot of time on identifying proper incentives for aligning all the different parties. Blockchain technology provides a mechanism called Smart contracts, which can also be used to implement the incentive mechanisms for different traceability targets. It would augur well for IDB to think about incentives as one-time value and as ongoing mechanism to keep the system running.

Ecosystem: Another important aspect of the traceability solution is the creation of necessary ecosystem around the solution. Blockchain itself does not guarantees authenticity of data – if garbage data goes in the system, the output would be garbage as well. It is imperative for IDB to think about ways to ensure proper collection of data. For example, usage of IOT (Internet of Things) devices or RFID tags could enable data uploading at various points of the chain sans any manual intervention. And once a basic system is in place, IDB can also start thinking on different possible ways the data, available on the system, can be used.

Governance Policy: One important aspect of blockchain based system is to decide if the system is going to be permissioned or permission-less. A permission-less system is one where any actor could be a part of the system, such as the bitcoin or Ethereum blockchain, whereas a permissioned system is the one where permission from a central authority is required before an actor can access the system. Most supply chain blockhain solutions today are permissioned systems. This is another decision IDB needs to make, as it affects who will maintain the solution. Who owns the IP of the solution if it is modified for this particular use case? Further, IDB also needs to think about the access rights different actors across the value chain would have on the system. Based on the kind of influence different actors have on the system, IDB might want to restrict access for some of the actors to read only or write only or both. Another important question for IDB could be to think about billing actors for accessing the system, if IDB believes that the system is providing enough values to those actors.

Standards: The last important feature of the framework is Standards. One must have requirement for a single system to exist across multiple stakeholders is the standardization of information. Before IDB rolls out a traceability system for any of the food value chains, it must figure out the standards required for supply chain data, the quality data, and the item specific data that it plans to capture over the blockchain. It also needs to figure out the structure of the data that would be fed by the various parties into the system, and the way the data will be shown to the multiple parties.

Appendix 1: Resource Report

References:

Kassem, Mohammed H. (2015). Pilot study on Mapping Tomato Value Chain and potential options to reduce losses in Nubaria, ARE. Available at: http://repo.mel.cgiar.org/handle/20.500.11766/4509

Ge, Lan, Christopher Brewster, Jacco Spek, Anton Smeenk, and Jan Top. (2017). Blockchain for Agriculture and Food; Findings from the pilot study. Wageningen, Wageningen Economic Research, Report 2017-112. Available at: https://www.wur.nl/upload_mm/d/c/0/b429c891-ab94-49c8-a309-beb9b6bba4df_2017-112%20Ge_def.pdf

Amit Ganeriwalla, Michael Casey, Prema Shrikrishna, Jan Philipp Bender, and Stefan Gstettner. (2018). Does your supply chain need a blockchain? Available at: https://www.bcg.com/en-us/publications/2018/does-your-supply-chain-need-blockchain.aspx

Kim, Henry M., and Laskowski, Marek. (2018). Toward an ontology-driven blockchain design for supply chain provenance. Available at: https://onlinelibrary.wiley.com/doi/10.1002/isaf.1424

Casey, Michael. (2017). Odd Bedfellows? Blockchain Developers Can Learn to Love the World Bank. Available at: https://www.coindesk.com/odd-bedfellows-blockchain-developers-can-learn-love-world-bank

Casey, Michael. (2018). World Bank Bond Blockchain Offers Key Insights. Available at: https://www.coindesk.com/the-power-of-private-blockchains-is-beginning-to-show

MIT Technology Review Editors. (May/June 2018) "Explainer: What is Blockchain" *MIT Technology Review*. Retrieved from https://www.technologyreview.com/s/610833/explainer-what-is-a-blockchain/

FAO. 2012. Global Food Waste and Loss – Prevalence, causes and prevention. Rome

Project report "Productivity and Andean Fruit Competitiveness" developed by the National University of Colombia, Sourced by IDB.

Castilla A., A., & Hernandez D., H. H. (2009). Caracterización de la cadena productiva del aguacate en el departamento de Bolívar 2008, mediante un modelo de simulación de redes, 1–142. https://doi.org/10.1017/CBO9781107415324.004

Becerra, César,   Cárdenas, Andrés, Gutiérrez , Diego F. (2018) Final Report: Study to reduce first-mile food loss in agricultural chains - LOGYCA/RESEARCH

Interviews:

Brigid McDermott 5/6/19 (Skype)
IBM Food Safety Project

Logyca Research team – 4 /23/ 19 (Skype)
Yohany Andrés Jiménez
Cesar Becerra
Andres Cardenas
Diego F Gutierrez

Christopher Mejía Argueta - 4/18/2019 (In person, Cambridge MA)
Director, MIT SCALE Network - Latin America
Director, MIT Graduate Certificate in Logistics and SCM (GCLOG) program
Director, MIT Food and Retail Operations Lab

Alysia ALISA DiCaprio, 3/1/19 (Skype)
Head of Trade and Supply Chain, R3

Inma Borrella, PhD   3/1/19 (Skype)
MITx Micromasters in SCM, Blockchain Research Group

Alexis H. Bateman 2/28/19 (Skype)
Research Scientist, MIT Center for Transportation & Logistics
Course Lead, MITx MicroMasters Program
Director, MIT Sustainable Supply Chains

Leonardo Bonanni   2/20/19 (Skype)
Founder CEO, Sourcemap

Mark Weber: 2/20/19 (in-person, Cambridge MA)
IBM – MIT AI lab

Eric Piscini 2/18/2019 (Skype)
CEO, Citizen’s Reserve

Rafeal Anta, 2/4/19 (Skype)
IDB

Written Correspondence:

Claire Kneller and Sam Gillick-Daniels, warp.org

Priya Sampath
From: Sam Gillick-Daniels <Sam.Gillick-Daniels@wrap.org.uk> Sent: Tuesday, March 12, 2019 9:28 AM To: Priya Sampath; 'Sturzenegger, German' Cc: Michael Casey; Rohit Sharma; Calatayud, Maria Agustina; Claire Kneller Subject: RE: Supply Chain Data for Mexico
Dear Priya, German,

My apologies for the delay in getting back to you. Unfortunately I lost sight of this during and after my time out of the office.

Claire has already mentioned the sources of data that I was going to refer to; SAGARPA and SIAP are the best sources of production data. As far as we can tell, this is pretty high-accuracy for certain commodities since it is based (currently) on satellite imagery and algorithms that estimate quantity from those images, although their post-harvest loss data relies on assumptions (like most of the world to be fair). In addition, some of the larger companies further downstream (e.g. Nestle and Walmart for a start) will have data on quantity purchased and waste. On the whole, the kinds of things you are looking for are difficult to find from publicly available sources.

If you would like to engage us directly on mapping out the sources of data and gaps, we would be happy to discuss further.

Kind regards,

Sam

From: Priya Sampath <sampathp@mit.edu> Sent: 26 February 2019 18:33 To: Claire Kneller <Claire.Kneller@wrap.org.uk>; 'Sturzenegger, German' <GERMANSTU@iadb.org>; Sam Gillick-Daniels <Sam.Gillick-Daniels@wrap.org.uk> Cc: Michael Casey <caseymj@mit.edu>; Rohit Sharma <sharmar@mit.edu>; Calatayud, Maria Agustina <MCALATAYUD@iadb.org> Subject: RE: Supply Chain Data for Mexico

Thank you German and Claudia.

To add a bit more color to what German has said below:

In order to be strategic about which part of a supply chain we should be tracking, in order to derive the most benefits from a waste reduction and provenance standpoint, we need two types of information.

1. data on the quantities of the product moving through various parts of the supply chain, 2. Information about the stakeholders / actors at each step – e.g. post-harvest, who are the actors involved, what activities do they participate in?

We are beginning to realize that this is easier said than done, and yet – in order for us to develop meaningful guidance and advice for those wanting to implement solutions, we need SOME data and knowledge about actors.

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Since our focus is on perishable goods in Latin America, if you have any information on perishable supply chains, it will help immensely in moving us along.

Best, Priya

From: Claire Kneller [mailto:Claire.Kneller@wrap.org.uk] Sent: Tuesday, February 26, 2019 12:22 PM To: 'Sturzenegger, German' <GERMANSTU@iadb.org>; Sam Gillick-Daniels <Sam.Gillick-Daniels@wrap.org.uk> Cc: Priya Sampath <sampathp@mit.edu>; Michael Casey <caseymj@mit.edu>; Rohit Sharma <sharmar@mit.edu>; Calatayud, Maria Agustina <MCALATAYUD@iadb.org> Subject: RE: Supply Chain Data for Mexico

Dear German and MIT colleagues

Firstly, I'm copying my colleague Sam who led on the data side of things for Mexico.

Secondly, as I'm sure you're finding with the project, there is a huge challenge with a) the existence of data in the first place, b) getting hold of it where it does exist and c) quality.

There will be some data for each of the stages you list below but the quality and availability will be wildly variable plus it will be held by different agencies. Sam can confirm but I am sure SAGARPA has data on production in different regions (though consumption is a different matter, I think SIAP has the data on this!). This will vary by region and crop type.

The quantity of on farm and post harvest loss is the big question – again, some data exists but the quality is hugely variable (methodologies can range from surveys to in field measurement – we have some evidence to suggest these can vary by up to double, see here http://www.wrap.org.uk/cy/content/foodwaste-primary-production-preliminary-study-strawberries-and-lettuces) and again, for different products you will find different data sets.

I'll let Sam add to this in case he has a recommendation for a particular supply chain that might be better than others.

Best regards Claire

From: Sturzenegger, German [mailto:GERMANSTU@iadb.org] Sent: 26 February 2019 16:38 To: Claire Kneller Cc: Priya Sampath; Michael Casey; Rohit Sharma; Calatayud, Maria Agustina Subject: Supply Chain Data for Mexico

Dear Claire,

Hope this email finds you well. We are working with our MIT colleagues at DCI on identifying the applicability of blockchain technologies to increase supply chain traceability and, consequently, reduce food waste. The constrain we

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have is access to data. Namely, data for an specific supply chain that would allow us to develop/run the model. The end product would be a toolkit for mainstreaming blockchain technology for higher traceability/lower food waste.

We are thinking that you guys may have access to data given the Mexico study, particularly for the hotspots you identified. Below some description of the type of data we need. I am letting my MIT colleagues to give you more details on that.

It would also be awesome that WRAP be part of the process as well, given the expertise on the subject.

Let us know what you think. It might be useful to schedule a short call to give you more details on the scope and type of data.

Best,

G. Type of info: 1. Amounts produced in certain areas (how much land is dedicated to the cultivation of the crop and how much is consumed). 2. Waste data at harvest and during handling on site 3. Waste data during Post-harvest handling and storage 4. Info on transportation between the storage site to various points of transit, till the commodity reaches either the final agro-processing site, or the supermarket / wholesale market. This can involve several stops. 5. Waste data at retail POS, like supermarkets.