Blockchain use cases for food traceability and control

A study to identify the potential benefits from using blockchain technology for food traceability and control

Axfoundation, SKL Kommentus, Swedish county councils and regions, Martin & Servera, and Kairos Future.

This project has been set up to identify the potential of blockchain technology within food transparency and control. Partners in the project are Axfoundation, SKL Kommentus (part of The Swedish Association of Local Authorities and Regions), Martin & Servera (Sweden's largest food service company), Kairos Future, and Sustainable Public Procurement – a collaboration between the Swedish county councils and regions.

Summary

Purpose

The purpose of this project is to:

- Identify the current state of food traceability and control, and technologies and projects that can be valuable in designing blockchain solutions.
- Identify blockchain technologies and projects that can be applied within food traceability and control.
- Show examples of how the current processes can be improved using blockchain technology. These areas of use can then be foundations for potential pilot projects.
- Write a report and communicate the results to public authorities, the retail and food industry, in order to stimulate interest and knowledge of the potential with the blockchain technology.

Challenges today

The food supply chain is the most complex and fragmented of all supply chains. The production is found all over the world both on land and in water. A lot of the producers and intermediaries are difficult to identify and track. For all the participants in the production chain this creates uncertainty and risk. Mitigating this uncertainty comes at a cost, and the outcome may still be insufficient.

Examples of problems that have been difficult or impossible to solve with current technologies include establishing reliable provenance and preventing fraud and counterfeiting. These issues can have knock-on effects on public health and the environment, and reduce financial costs of unnecessary recalls of food products.

The blockchain enable privacy, limit manipulation, and lowers barriers to entry

Traceability and control is possible without the blockchain. There are for example services where you can look up the origin of fish at www.thisfish.info or with fTRACE. However, three major benefits with the blockchain are: 1. The data cannot be manipulated; 2. The supply chain can secure traceability and control without all participants disclosing all their customers and suppliers to a central party. The level of privacy to enforce can be decided by the participants in the system and; 3. The blockchain creates trust in low cost IT solutions. You can use email, Word, mobile phones etc. and still be sure data is accurate. This allows for example rural farmers and independent truck drivers to integrate with the system.

Three identified areas of use

Three areas of applications are identified that are interesting to investigate further and might prove feasible to be areas to develop pilots and proof of concepts around.

1. Conditions at the production facility

Conditions at product sites, like factories, fields, or fishing boats, are today difficult to verify and include labor conditions, environmental conditions, quality control in production etc. The blockchain could be used to make it very difficult to falsify or misrepresent conditions in production. A digital representation of the conditions, such as a photo or a digital file, can be stored at the production facility, or in a mobile app. This could for example be a photograph of a catch of fish or a factory during operation. A verification of the same files, a digital fingerprint in the form of a hash, is published in a blockchain. Time and location cannot be manipulated since it is recorded in the blockchain. By making random inspections an inspector can then verify that the photograph corresponds to the actual conditions at the facility, the workforce, and that the outcome/production corresponds to the one reported to the blockchain.

2. Tracking of food volumes in the supply chain

Identities of individual grains, beans or bulk commodities often bought on a spot market such as coffea, tea, oils, sugar, cacao etc are difficult or impossible to track. However, with the blockchain it is possible to track the total volumes bought and sold for each participant in the supply chain. The benefit from using the blockchain is that no central party needs to be trusted in getting all the data on transactions and actors, while still for example letting volumes be transparent for everyone in the chain. To exemplify; with the blockchain, the volumes of organic soybeans sold cannot be higher than the volume of organic soybeans bought for any party in the supply chain. Also, with blockchain it's not possible to buy ordinary rice and mix it with a small portion of basmati rice, and sell the entire volume at the higher basmati rice price since the tracked amount of basmati rice going in to the chain can not be higher than the volume going out.

3. Tracking of food items in the supply chain

Blockchain technology enables possibilities to track a particular package of food, can or any item to which you can put a unique identifier such as a barcode, QR code, or a RfID transmitter. Compared with existing technologies, the blockchain can easily regulate who gets access to the information and identities behind each product. Integration between regular transaction data and more complex data such as sensor data of temperature and humidity can be directly connected to the product. The cost and speed of implementation can probably benefit from an integration with existing product IDs such as the ones provided by GS1[1].

Priorities going forward

Those familiar with blockchain technology have heard of Bitcoin and cryptocurrencies. If we compare blockchain technologies for food with areas like finance, there are differences. Food is a physical product and the connection between the real world and the digital world has to be managed. Another area of concern is that many food products are small and inexpensive. There is a risk that tracking of every package and seed become expensive. The blockchain enables integration of simple hardware and cheap software but we need to make a system with low transaction costs too.

The conclusion from this study is that the prospect for blockchain solutions within food traceability and control are substantial. A challenge is that the fragmented industry can make blockchain solutions difficult and time-consuming to implement.

Our ambition is to show the benefit of solutions in areas where we can add value within a few years. We have to develop solutions that either have a large value in the Swedish food supply chain alone or are likely to be implemented or copied in other countries. Two areas which are considered attractive are to increase transparency of the conditions at the production facility and the traceability of fish.

1 GS1 provides a set of open standards enabling data sharing in a standardized manner that enable interoperability between different business partners. In this context, GS1 standards can be used to describe transactions and events in a way that every actor along a supply chain can interpret these the same way and blockchain technologies could be used to share this data in a secure and trusted manner.

Content

About the project

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Background

Food and food production is one of the largest industries in the world. It is also the most fragmented industry with production scattered all over the world. The food supply chain also becomes more global over time[2]. Keeping control of the supply chain of food is therefore a costly and difficult task. The dependence on trust in third party operations, ethics in production, transportation, to name a few areas, is evident. Stamps and documentation, IT-systems, certificates, food origin, mixing of food, the use of chemicals etc. are areas where fraud or ignorance can create problems on a large scale. At worst, it can cause health problems, even deaths.

While existing IT-solutions have mitigated some of these challenges there is still a lot of uncertainty. Integration costs remain high, there is still a lot of undetected fraud, and transparency levels are insufficient to comply with the current and future demands of consumers and other stakeholders. A new area of technology, the blockchain, can potentially solve many of the remaining problems for food transparency and control.

Background to the blockchain technology

The most well-known use case of the technology is Bitcoin and cryptocurrencies. However, the transaction capacity and the cost per transaction in Bitcoin is prohibitively high. In the early summer 2017 the average cost was $4 per transaction, and there has been no major increase in transaction capacity to date. Bitcoin may or may not be an attractive store of value, but the impact on society will likely stay small, as long as transaction costs are this high.

The underlying technology, the blockchain, may on the other hand prove to be extremely valuable to society. It may be a founding block or an

2 http://ec.europa.eu/chafea/documents/food/food-fraud-2324102014-rey_en.pdf

emerging set of tools for the digitization of society. The discussion of solutions started to expand beyond Bitcoin and focus on blockchain and distributed ledger technology around 2015.

The influential bank Goldman Sachs stated the following in December 2015 regarding blockchain technology: ”Silicon Valley and Wall Street are betting that the underlying technology behind [the Bitcoin hype cycle], the Blockchain, can change ... well everything.”[3] In a survey of experts by the World Economic Forum in 2015, the majority (57% of respondents) estimated that 10% of the world's GDP will be registered in a blockchain by the year 2025[4].

Recent events in 2017 such as the World Economic Forum, South by Southwest and the Mobile World Congress have made the growing interest in the blockchain still more evident.

Blockchain technology for food

The interest in blockchain technology for traceability and control has risen more recently. A pilot project where IBM and Walmart have tracked mango in the USA and pork in China has received a lot of attention. A second phase of the project is announced and the project now includes 10 of the world's largest food manufacturers and retailers.

3 Business Insider UK, GOLDMAN SACHS: 'The Blockchain can change... well everything' (http://uk.businessinsider.com/goldman-sachs-the-blockchain-can-change-well-everything-2015-12)

4 http://www3.weforum.org/docs/WEF_GAC15_Technological_Tipping_Points_report_2015.pdf

The increased need for food traceability and transparency

United Nation Global Compact defines traceability as "the ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labor (including health and safety), the environment and anti-corruption"[5]. Traceability of food is a long-standing issue which has really come to the fore in the last couple of years, spurred largely by the 2013 horsemeat scandal where horsemeat was sold mislabeled as beef[6]. Because of the scandal, public confidence in food supply was damaged and consumers became much more aware and concerned about the food they were eating. Businesses are today increasingly looking for solutions to food traceability in their supply chains and hence opportunities to restore and assure public confidence in food security and supply. Increased traceability and transparency is a great challenge facing the food industry. In the following three sections we will explore: (1) drivers for the increased need of traceability and transparency; (2) obstacles for traceability and transparency and; (3) examples of existing systems for traceability and transparency in global food supply chains today. This chapter does not claim to give a full descriptive of drivers and challenges, it is limited to and should be seen as an overview.

Drivers for the increased need of traceability and transparency

Food fraud

Food fraud is defined as the act of intentionally altering, misrepresenting, mislabeling, substituting or tampering with any food product at any point along the "farm-to-table" food supply chain. It can occur in the raw

5 A Guide to Traceability - a Practical Approach to Advance Sustainability in Global Supply Chains, United Nations Global Compact (2014)

6 https://www.theguardian.com/uk-news/2017/jul/26/horsemeat-trial-shines-light-international-fraud

material, in an ingredient, in the final product or in the food's packaging[7]. Apart from economic losses, food fraud causes damages such as loss of confidence in government regulatory systems around food safety, impact on public health and loss of consumer confidence[8]. It is more difficult to discover fraud in complex and global food supply chains, where local markets get reliant upon the food safety systems of the countries they import from. According to the Consumer Goods Forum, increased problems with food fraud are driven by the economic gains it enables. Fraud "follows the money" and occurs where significant price differences between commodities motivate substitution and increase pressure on corrupt suppliers to commit food fraud. The National Food Agency in Sweden argues that the risk of being "caught" is low due to increased globalization of food supply chains and hence there is a potential for actors in that chain to be anonymous[9].

Ensuring that sustainability claims are true

Areas that Swedish authorities, municipalities and public procurement representatives are struggling with include environmental problems and proof of organic production, ensuring human rights and working conditions, chemical usage, quality, guarantees of third-party certificates, conditions in transports throughout the chain, sustainable resource usage and more. These challenges have partly followed by the transition to a global and industrialized food production system with complex global food supply chains. This is further complicated by the fact that food production is increasingly concentrated to developing countries, often struggling with high corruption levels and insufficient environmental, social and economic regulatory frameworks, fueled by increasing market and consumer pressure for low prices, 24/7 availability and quality. A lack of a common playfield regarding important aspects of sustainability, health

7 http://fsns.com/news/what-is-food-fraud

8 https://foodsafetytech.com/column/fighting-the-reality-of-food-fraud/

9 Livsmedelsverkets arbete för att motverka livsmedelsfusk, Livsmedelsverket (2017).

and quality creates an increased need for traceability and transparency in the supply chains. Companies and public authorities need to have a way of verifying sustainability claims and attributes linked to their products, commodities and production practices. Hence, organizations and stakeholders in industries with complex supply chains facing sustainability challenges, such as the agriculture industry, have started to come together to improve their supply chain management and trace commodities collaboratively[10]. The main driver for this is the need for reducing risks which ultimately helps businesses and authorities to identify and address problematic raw materials, commodities or unsustainable practices along the value chain[11].

Inputs from a Swedish perspective

- In Sweden, almost 20% of GDP comprises public procurement and hence it is of major political interest. The Country Councils and Regions has prioritized eight high risk areas in public procurement, and food is one of them. According to them, claims and follow up in public procurement are critical tools to work proactively with change in supply chains. SKL Kommentus (central procurement body owned by the Swedish Association of Local Authorities and Regions) is one example where local authorities come together to collectively promote sustainable public procurements practices in accordance to SDG 12:7[12]. Through the coordinated audit service Hållbarhetskollen SKL Kommentus enables local authorities to follow up on sustainability requirements and hence drive improvements in the supply chain.
- A big challenge associated with public procurement is to coordinate audits and controls which can ensure that sustainability claims are true. The follow up is often complicated due to the number of intermediaries and the limitations of third-party audits. Often,

10 A Guide to Traceability - a Practical Approach to Advance Sustainability in Global Supply Chains, United Nations Global Compact (2014)

11 A Guide to Traceability - a Practical Approach to Advance Sustainability in Global Supply Chains, United Nations Global Compact (2014)

12 https://www.sklkommentus.se/inkopscentral/vart-arbetssatt/hallbarhetskollen/

the trace of commodities upstream the supply chain "get stuck" as a consequence of producers and middlemen holding on to vital information, claiming that they need to maintain propriety information on sourcing and suppliers for competitive reasons. Chemicals is seen as a particularly challenging area in this regard.

- Furthermore, third party audits are limited to pre-determined controls and often, procured international auditing organizations in their turn are employing local auditors.
- Challenges with traceability and audits are further associated with the character of the product or commodity, and composite[13] products are said to be particularly difficult to trace.
- Third party-labeled products, such as MSC-labelled fish or Fairtrade-labelled coffee or bananas are also of particular interest since the motivation for fraud is higher for these products[14]. Furthermore, commodities that are reloaded or repackaged along the chain create incentives for fraud.
- According to Martin & Servera (Sweden's leading wholesaler and supplier to restaurants – both in the private and in the public sector) and representatives from municipalities in Sweden, all commodities with the potential for added monetary value are high risk products. This includes bulk commodities, composite products, meat and charcuteries, certified commodities, fish and fresh food.
- These are examples of areas that have been identified as challenging regarding traceability and control:
    - Bulk commodities: coffee, tea, cacao, sugar, olive, palm and coconut oils, vanilla.
    - Composite products: especially composite meat products.

13 https://www.food.gov.uk/business-industry/imports/compositeprods

14 Interviews with representative from a number of Swedish municipalities

- Meat, charcuteries and the use of antibiotics in livestock.
- Certified commodities such as MSC-labelled fish.
- Fish, due to big problems with illegal, unregulated and unreported fishing at sea.
- Fresh food, especially fruits and vegetables.

Regulatory demands and legal requirements

Respecting national or international legal requirements or guidance directives related to sustainability, quality and health issues, is a driver for any company. According to the European Commission, every European Citizen has the right to know how the food they eat is produced, processed, packaged, labeled and sold. The central goal of the European Commission's Food Safety policy is to ensure a high level of protection of human health regarding the food industry[15]. The European Commission Food Law Regulation 178/2002 contains general food traceability requirements, such as that food must be traceable through all stages of production, processing, and distribution[16]. The 2030 Agenda for sustainable development was adopted in a world where food insecurity presents an enormous global challenge and several of the sustainable development goals (SDG) address food[17]. United Nations has highlighted achieved food security as a continuing development priority and has included it as part of SDG 2. Also, SDG 12 for sustainable consumption and production highlights that economic growth and sustainable development requires that we urgently reduce our ecological footprint by changing the way we produce and consume goods and resources[18], which is also an important driver for increased traceability and transparency in the global food system.

15 https://ec.europa.eu/food/

16 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:031:0001:0024:en:PDF

17 https://www.unglobalcompact.org/what-is-gc/our-work/environment/food-agriculture

18 Transforming the World: The 2030 Agenda for Sustainable Development, United Nations

Included in the Swedish National Food Strategy is the following assessment: "Whatever their socioeconomic group, consumers should have the opportunity to make informed and conscious choices about their food. The relevant authorities should continue to play an important role in compiling and disseminating information about safe food, good eating habits and sustainable food production" . The Government has mandated the Swedish Board of Agriculture to work closely with the Swedish National Food Agency to promote digital innovation by making information in the food supply chain available for purposes such as highlighting sustainability issues and increasing competition within the sector. This work will continue until 2018[19].

Stakeholder pressure

Consumers, NGOs, governments, suppliers and buyers increasingly demand more transparency regarding the origin of their products and materials as well as the conditions under which they were produced and transported along the value chain. Companies are today facing rapidly shifting consumer preferences and demand for rapid access to reliable and relevant information whenever they want it, spurred by the power of social networks and media[20]. Consequently, large companies, often of big brands, are increasingly vulnerable to external pressure due to the needs to protect brand reputation and ultimately their business. Supply chain management today must therefore consider a wider range of issues and look at a extended part of the supply chain. The implication of this is an increased need for cooperation among partnering companies in sustainable supply chain management.

19 http://www.government.se/498282/contentassets/16ef73aaa6f74faab86ade5ef239b659/livsmedelsstrategin_kort-version_eng.pdf

20 https://www.foodsafetymagazine.com/enewsletter/challenges-of-food-traceability/

Traceability in global food supply chains today

Obstacles in today's supply chain

Supply chain complexity

Globalization of the business sector has dramatically increased the cross-border movement of commodities and goods, and hence increased the complexity of global supply chains. Today, it is often difficult for companies to trace each and every step in the journey of a specific product back to its origin of production (see illustration 1 below). Multiple actors with different systems and requirements may contribute to production across international borders, and some areas in a supply chain may be especially dim. Consequently, this is a complex issue for companies since traceability requires the engagement and collaboration of actors along the entire supply chain in order to trace a product's history.

Illustration 1: Complexity of food supply chain for fresh food from "farm to fork" (GS1 Global Traceability Standard, GS1 (2017))

Overlapping and conflicting demands from different regulators

A complicating dimension to traceability of food are the companies' need to comply with varying and evolving regulations[21]. There are many overlapping and conflicting demands from national regulators around the world, proclaiming different regulations on allergens, trace elements, pesticides and more[22]. In today's global economy, supply chain traceability involves complying with multiple jurisdictions for each country and region involved in the supply chain. As a result, each organization may face a multitude of internal and external traceability requirements[23].

21 GS1 Global Traceability Standard, GS1 (2017)

22 https://www.foodsafetymagazine.com/enewsletter/challenges-of-food-traceability/

23 GS1 Global Traceability Standard, GS1 (2017)

Complexity in regulations may also cause difficulties for national authorities' responsibilities. In Sweden, the National Food Agency is together with the National Veterinary Institute and the Swedish Board of Agriculture responsible for food risk management and assessment. Together with the responsibility of coordinating food inspections by the regional country authorities and the responsibility of carrying out food inspections by the local municipalities[24], this divided responsibility can cause problems since prerequisites may look very different for different actors. Furthermore, Swedish authorities describe difficulties in assessing food fraud since control procedures comprise such a wide range of product categories and endless of varieties of companies. Food control systems then become a guessing game since violence against regulation is hard to assess.

Lack in digitalization and weak supporting systems

The global food supply chain needs to be digitized in order to support full traceability. Today, weak technical systems aggravate rapid response times and efficient flows of information. Interoperability from one system to another (different systems talking to each other) is lacking, meaning a lot of auditing and controls today are being carried out manually to ensure, for instance, sustainability claims. Luckily, digitalization and technology innovations such as blockchain are opening for efficient and low-cost solutions, overcoming these challenges.

Examples of existing systems for traceability and transparency in global food supply chains today

Already today, there are alternatives to increase traceability along a food supply chain. GS1 Gobal Traceability Standard provides various points in the supply chain, for instance the trade items, logistic units, parties and

24 EU Food Safety Almanac, German Federal Institute for Risk Assessment (BfR) (2017)

locations, with unique identifiers. We recommend their report as a guide to current traceability and control[25]. Automatic data capture techniques, such as barcodes and RFID-tags, are used on products or pallets across the supply chain to gather the traceability data based on the activities in the supply chain[26]. Also, DNA markers[27] and isotope tests are emerging techniques to address traceability of food through the use of random sample test.

According to GS1, a complete traceability system will include components that manage [28]:

1. Identification, marking and attribution of traceable objects, parties and locations.
2. Automatic capture (through a scan or read) of the movements or events involving an object.
3. Recording and sharing of the traceability data, either internally or with parties in a supply chain, so that visibility to what has occurred may be realized.

However, due to the obstacles described, with complex and long supply chains, characterized by numerous middleman and lacking transparency and insufficient supporting systems and digitalization, many challenges still remain. Also, automatic data capture techniques are often costly, hard to implement and difficult to apply to volumes and bulk items. In many cases the challenge of traceability is simply a lack of records. Increasingly complex products require more complete traceability systems. Manually written documents lead to human error, difficulties in quickly sorting products and slow trace back/forward ability. The way forward is electronic data management systems and digitalization of the processes [29].

25 https://www.gs1.org/sites/default/files/docs/traceability/GS1_Global_Traceability_Standard_i2.pdf

26 http://www.gs1.se/globalassets/traceability/kom_igang_sparbarhet_retail.pdf

27 https://www.newfoodmagazine.com/news/34815/block-chain-food-fraud/

28 GS1 Global Traceability Standard, GS1 (2017)

29 https://www.foodsafetymagazine.com/enewsletter/challenges-of-food-traceability/

The blockchain is a new set of tools for digitization

One of the most common questions regarding blockchain solutions is why do you need them or why don't you use existing technology? The simplest answer to that question is that they enable certain functions that did not exist before, and that traditional databases and architectures are unable to perform.

The reason blockchain technology is interesting is that there are certain functions that are very valuable for the digital world, that hasn't been invented before the blockchain.

1. Digital units impossible to copy

If you want to make a representation of a food product or commodity with certain characteristics and track that item in a supply chain, it is important that you cannot make copies of that item. Otherwise you can for example claim that you sell the same organic cans of tomato soup by reusing the same digital identity over and over again.

If we use the blockchain we can ensure there is no risk of copying and "double spending" or "double selling" a particular item of food. Each characteristic of the food, such as certificates of fair trade or limited use of antibiotics, can not be duplicated.

A central database can accomplish the same objective, but only if you completely trust the holder of the database. On top of that the parties being part of the supply chain and their actions will be public, or known by those who can access the database, legitimately or by illegal means. This might not be good for competitive reasons and privacy. Not everyone wants to disclose their business practices.

Bitcoin was the first to solve this 'double-spending' problem. Many central banks and commercial banks have during the past year communicated that they are looking at the opportunity to issue digital cash on the blockchain, or with distributed ledger technology. No major central bank has done so, and none has said they are looking at doing it with any other technology. As far as we know, the blockchain is the only solution being investigated by this growing group of central banks and commercial banks. Perhaps the main reason for this is the possibility to create transferrable digital units, which are more or less impossible to copy.

2. Digital files that can't be manipulated

While digitization has come far in many respects there is another property, except for being possible to copy, that traditional IT solutions has not yet solved. It is very difficult to know if a digital file, photo, contract etc. has been manipulated. As an example, the Swedish law states that any changes in the bookkeeping of a company has to be registered with a notification of who made the change, why it was made, and when was it made. The problem with this rule is that it is impossible to audit. Any savvy IT person can make changes in the registry of the bookkeeping that cannot be detected. There is no practical way for a manager or organization, an accountant or tax authority to know who made these changes and when they were made, or to notice at all that any change has been made[30].

With blockchain technology it is now possible to make sure that a digital file, register, certificate of ethical production, photo or video etc. is still the same as it was when it was first registered in the blockchain. The hashing technology and the blockchain is the only known technology that can do this. If we want to digitally represent for example digital files, authorizing

30 Modern technologies have made it possible to monitor all updates, for example in a cloud environment, so a person who wants to manipulate the data base to be able to manipulate the external environment as well, which makes is more complicated but possible.

food production and conditions at the production facility, or data files of the bookkeeping regarding food purchases and sales, it is of paramount importance that they are impossible, or at least very hard, to manipulate. The blockchain is the most trustworthy solution for this.

3. Digital processes that can't be manipulated

A third problem the blockchain has solved is securing a process. The most discussed example of such process is trade finance, where a sequence of actors have to confirm what they are doing at various stages in the agreement. They have to take responsibility for the goods being shipped and confirm the process for actors throughout the chain of transportation. If the container comes with coal and not bananas, you want to know who is responsible in the supply chain and who received and kept goods, and money they shouldn't.

Securing a process is believed to be crucial in the development of IoT, Internet of Things. This is an area that will be of great importance in the food supply chain since the amount of data increasingly will be collected from sensors throughout the supply chain from farm field to fork.
It is also valuable in a contract with many parties, such as a purchasing contract of real estate, a blockchain use-case made in Sweden[31]. It is important for all parties like banks, real estate agents, buyer, seller etc. involved to be confident that all other parties are signing the contract in an right order. This also makes it possible to proceed even if some of the actors are not physically present.

31 https://www.kairosfuture.com/publications/reports/the-land-registry-in-the-block-chain-testbed/

4. Low barriers to entry

This is not entirely unique for the blockchain, but all three aspects described above can be integrated at a low cost. The blockchain technology enables trust in low cost technologies that under other circumstances are considered insecure.

The blockchain can make verifications of any digital record trustworthy. An e-mail, a photo, or a SMS are usually perceived as insecure. This is of paramount importance in the food supply chain since a large number of farmers, actors have very limited IT capabilities. A system that requires every farmer to have a SAP-solution with Oracle databases will never be realized. The blockchain on the other hand makes it possible for small farmers and truck drivers or a fisherman out at sea to enter trustworthy data to the supply chain with a simple smart phone. Data and processes cannot be manipulated, because hashes (digital fingerprints that are stored in the blockchain) will reveal any manipulation or change of the data or processes in the system[32].

32 For more infomration on hashes and digital fingerprints see appendix.

Different blockchains

For a more complete introduction to the technology, see appendix 1.

Security levels of different blockchains

Securing data can be made on different levels of security and complexity. If we would rank a couple of alternatives we could mention:

1. **A digital fingerprint stored locally**
   An organization may store digital fingerprints, hashes, locally but separated from the original files or content. This makes it easier to know whether data has changed or been manipulated within your own organization.
2. **Digital fingerprints stored in a local hash tree**
   To make the system even more solid, each hash can be stored in a hash tree, also known as a merkle tree. The idea is that each hash is also combined with previous hashes into a single new hash. It then becomes very difficult to change the previous hashes without knowing that something has gone wrong. Controlling changes in internal data will be much easier in this system.
3. **Digital fingerprints in an external hash tree**
   To create trust in the solution, it is good to let an outside institution control the hash tree. This makes it significantly more difficult for the organization who has the original files to make changes that are not known to others. Scrive in Sweden is signing documents, e.g. a contract between two parties, which can be verified with an external partner, as an example[33]. You can also make a form of control of processes if the external host of the hash tree can separate validated hashes that correctly follow prescribed processes. This can allow some form of "smart contract".

33 http://www.scrive.com

4. **An external hash tree in a distributed ledger structure**
To prevent the hash tree from having a single point of failure you can create a shared database – a distributed ledger that is shared among the participants. With this solution, there is no single employee or organization who can manipulate the verifications in the database or the processes. This allows for sensitive transfers such as financial transactions, or transactions where it's unwise to rely on a single manager of the database. If we want to trade CO2 emissions in a blockchain, we need this level of security. It's unwise to have a single point of failure of data that is easy to monetize.
5. **An external hash tree in a public consensus database structure**
In a public distributed ledger or blockchain it is possible for anyone to be part of the validation process. No-one is in control of the system, but power to make changes is given to those running the system and providing most security to the solution. This cannot be controlled by public institutions, which is one of the benefits but also one of the problems. There is no protection to those who loose their assets, IDs etc. This risk can be mitigated with custodians, i.e someone who stores the private keys controlling the digital assets, but then those custodians can be hacked too. The distributed ledger may therefore be very secure, but the ecosystem around the solution can be vulnerable. Within traceability and control of goods such as food, public blockchains seems to be out of question today. Only private blockchains can be used due to high transaction costs and low capacity of public blockchains, e.g. Bitcoin and Ethereum.
6. **Hybrid distributed ledgers**
(This area is complicated, beyond most people's understanding, including the team in this project.) Since the transaction and storage capacity of public blockchains is limited, there are efforts to create

hybrid structures where the majority of transactions are made outside of the public blockchain. Confirmations of a group of transactions are then connected to the public blockchain. We can think of any of the above listed alternatives 1 to 5 being "anchored" or verified in a more secure blockchain.

Selection of blockchain solution for food

When we started this project we knew that transaction costs are important to address. About ten years ago, there was a lot of talk around RfID, another technology that can be of help within traceability and control. Walmart was one of the proponents, but the implementation was hindered at that time because of too high transaction costs vs. business value. RfID is now being implemented but not as fast as was first expected. When we talked to Paul W Chang, the head of blockchain supply chain solutions at IBM, he says Walmart learnt from the RfID experience; "When the executives of Walmart and IBM sat down to look at the pilot project of food traceability, the tracking of mango back to the farmer took less than three seconds instead of a week, which is common today. Both parties agreed that the blockchain solution must be offered in a price competitive way so that everyone can participate, otherwise we may not realize the full value from using it."

In the case of food, we are primarily interested in low transaction costs. In most cases the security levels don't have to be as high as for financial assets. Part of the reason is that you normally don't lose the food even if you lose the digital identities representing the food. Within financial services you may sell the digital assets and run away with the money. Within food this is not the case. Criminals who hack the system still haven't got the food and have a hard time making money from their theft of digital codes.

The optimal blockchain solution within food may therefore be similar to a digital asset blockchain but with lower demands on security – if this reduce transaction costs. For food, transparency and control, the security level 3 described below is necessary and in most cases security level 4 will be recommended. At least this is our hypothesis for now.

A general framework for the IT architecture

In this project we have looked into different technology providers. Companies we have interviewed specialized in the area of blockchain for food supply chains are IBM, Ripe, Provenance, and Chainvine. All of them are focused on tracking food rather than control. Here comes a short introduction to these companies. After that we make a general overview of key components for solutions in the area.

IBM

We met with Paul W Chang, the head of blockchain supply chain solutions, and Christina Claughton-Wallin, client executive, both at IBM.

IBM focuses on solutions for large enterprises. The main platform they use is Hyperledger Fabric, the most talked about blockchain within the Hyperledger open source initiative. This is also the platform they have used for tracking containers in an internationally recognized pilot project with Maersk, and a food tracking project with Wal Mart. The latter will now involve a large group of major global food companies and retailers like Dole, Nestlé, Unilever etc. Two good things with the IBM solution is the integration with existing EDI information in companies' ERP-systems and the use of GS1 standards for food products. These solutions facilitate integration with existing systems used by retailers, wholesalers, and food manufacturers.

Chainvine

We met with Oliver N Oram, CEO and founder, and Niclas Wigstrom, Co-founder.

Chainvine is a small startup that focuses on blockchain solutions for food. Their head of technology, Rajiv Mathur, has a background with distributed technologies and telecom. They started to focus on solutions with wine and are now looking more broadly into more food categories as well as integration with Internet of Things. They are blockchain agnostic and have clients who want them to work with both public and permissioned blockchains.

Ripe

We have spoken to Phil Harris, president and founder.

Ripe is a small startup focused on blockchain solutions for food. Their focus is on making very detailed information about the origin of the product, including sensors data. This usually requires more manual work but can distinguish more quality aspects. Ripe doesn't disclose the blockchain technology they use but say they have adapted one of the open source versions on the market.

Provenance

We have spoken to Jessi Baker, CEO and founder.

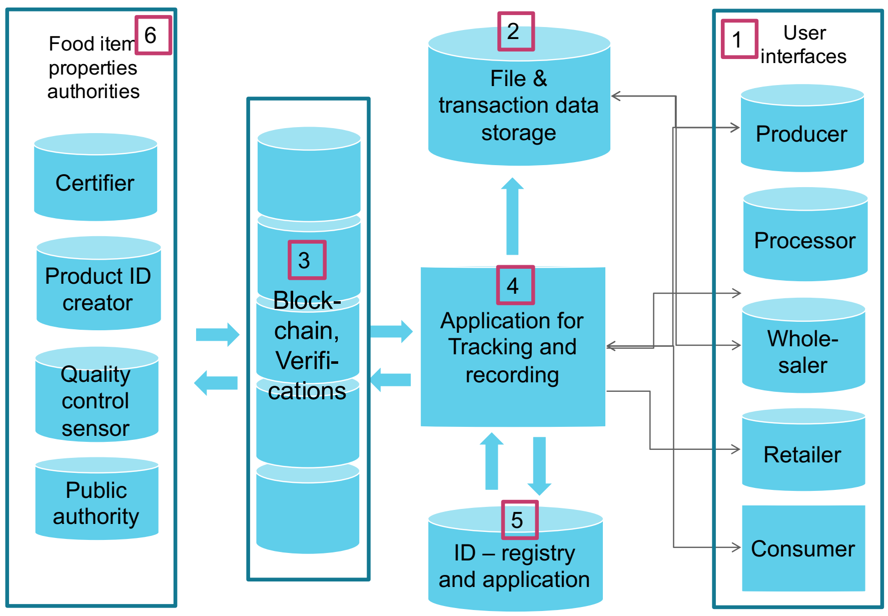
Provenance was the first to write a short white paper of a pilot with food traceability and the blockchain[34]. The report is also one of the best we have found today describing the case. Their described use case was fish from Indonesia. Provenance have shared many case studies and writings on their projects in 2014-2016, but have since been more secretively due to the increased competitor landscape and corporate NDA:s. Provenance

34 https://www.provenance.org/whitepaper

seems to have the broadest adoption of the technology providers we have talked to. They have 300 members and clients, like Sainsbury's and Unilever. They want to use public blockchains, like Ethereum, but have also started using a combination with Hyperledger to reduce transaction costs and increase transaction capacity.

Technical overview

There are six main parts of the blockchain solutions that we find rather generic, at least in the case of private blockchains. These components are described below.



1. User interfaces

The user interfaces are designed for different users. There are three main categories of user interfaces.

End-users - typically the consumer

These users are expected to use their mobile and a dedicated app for the solution. It is expected to be a read-only application in the first place and will therefore not require a log-in. The consumer will then be able to scan a barcode, Rfid-sensor or QR-code. Through this they can access the information related to that particular product. Depending on the choice of solution the consumer may access all the steps in the supply chain, or only the place of production and the description of the food.

Professional users – wholesalers, retailers, freight companies, farmers, processing and packaging companies

Each one of these will have an interface, either through mobile or desktop, or integrated in the ERP-system. They will know the previous and following parties in the supply chain as well as the food origin and various specifications of the food, and in some cases they will get more information than what is needed by the consumer.

Smart contract/software administrators

These users will administer the contract for the other users. If there are changes in the process or contracts that have to be made, this will be managed through this interface. The governance of the system can be organized with a public authority, or a company or group of companies, that is trusted for doing this. The contract code should normally be open source so that any changes are visible to all participants and can be challenged if there is a setup for governance of this.

2. The file storage

The information that is added to the blockchain is normally restricted. It will not contain all information, but instead contract verifications, hashes, and identification of who has added this information. If, for example, a farmer takes a photo of the crop and add it to the blockchain, the photo can either be:

1. Uploaded to the blockchain and fully transparent for the nodes in the blockchain, but this requires the blockchain to store a significant amount of information.
2. Uploaded to a separate database but accessed by the blockchain. Access can be restricted or open for everyone who interacts with the blockchain.
3. Stored in a database that is owned or controlled by the person or organization uploading the photo, but it is not possible to access through the blockchain. Only the creator of the file/photo decide who they want to share their data with.

3. The blockchain

The blockchain is the part where the verifications of files, contracts, and transactions are recorded and stored. This is equivalent to the distributed ledger. The nodes decide what is going to be committed to the blockchain, and what should not be accepted. There may also be nodes that are not part of the validation process but simply store the record.

In a public blockchains, such as Bitcoin and Ethereum, anyone is allowed to be a node and keep a copy of the ledger. They can be a node which verifies and accept transactions and information that is going to be stored in the blocks, or they can simply keep a record of what is committed to the blockchain by the others. In practice, those who want to be nodes which verify transactions need substantial processing power to have the chance to be part of the system. Due to the transaction costs, Bitcoin is not considered as an alternative in this project. Even if the transaction cost in Ethereum is significantly lower, transaction capacity is limited and we expect transaction costs to be a restriction in a price sensitive area like food. The hypothesis for now is that a permissioned blockchain will be most attractive, which means that only trusted partners are allowed to validate transactions and blocks. The validated and recorded content of the blockchain may or may not be published to the public.

4. Application/contract engine

The application or contract engine is a key element of the solution. The most well-known blockchain solution for applications is Ethereum. In Ethereum the contracts are called distributed applications. The applications are run on the blockchain by all nodes they are distributed. In some other cases, the contracts are not run on the blockchain – they are confirmed in the blockchain, we can say their verifications are embedded in the blockchain but the entire application is not run by the blockchain network. Many technology providers want their applications to be possible to run on different blockchains and this is much easier if the application is not run by the blockchain.

5. The ID and authorization

The actors who are going to authorize the different steps in the process have to be identified. This is one of the major challenges for digital solutions. In the case of Bitcoin, possession of the correct private key is sufficient authorization to spend the associated bitcoin. The problem with this is that the storage of the key becomes crucial. Most consumers are not capable of securely storing their private key in the long term. If the private key is lost or stolen, all Bitcoins are lost. In most cases the consumers trust a custodian to care for their keys. The problem is that the custodians have been hacked in some cases, like MtGox and Bitfinex.

In the case of food, security is less critical. IBM, Chainvine, Ripe.io, Provenance etc. are all technology providers that claim to have a solution and seem to want to handle the ID-creation and directory within the system, or rather create the ID-system, and let the administrators of the system be responsible for the ID-solution as well. The system then creates the private and public keys of the participants and may use extra security such as IP-addresses to control for authority of the actors. In essence, the ID provider should be liable for any damage done to the participants in case of a hack of the ID-solution. IBM might be big enough to handle this in many cases – but if the system is to be global there will be a need for a broader governance system. Smaller IT companies will need some external provider of trust, a public authority or major company, to the ID-solution even in a local implementation.

While the ID-solution is a major concern if the system is to be broadly adopted, the blockchain is also an enabler of ID-solutions. The blockchain may be the preferred technology to create ID-solutions in the future and it can be rather simple to add levels of security of an ID-solution with the blockchain. For example, if a public authority or a person wants higher security in form of a copy of a driving license, it is easy to make a copy and add that to the contract in the blockchain. The flexibility of the ID-solution is easy to adjust with the blockchain. Australia Post are developing an ID-solution on the blockchain, and now partner with the government ID-solution, GovPass[35]. Estonia has a blockchain like system for this purpose in operation.

6. Food item properties registrators

In the case of cryptocurrencies, there is no need for a real-world interpretation of the digital units. It's an open market, which decides if the digital units have a value, and apart from that, value has little meaning. In the case of food there are many organizations and authorities that can have an interest in labeling the food with their certificates. Public authorities may assign a particular quota of some kind of food. The public authority may assign a code to keep track of the farmer/fisherman/food producer etc. and their production. The amount produced or sold by the farmer of crop/fish etc. will then get this code in the blockchain.

A food item may have several characteristics which need to be trusted and therefore controlled by external auditing organizations or authorities. In these cases, the blockchain provides solutions for actors to keep track of the usage of specific characteristics or certificates associated with a certain food identity, such as Fair Trade, organic, antibiotic-free, MSC (Marine Stewardship Council), high nutritional value, non-GMO. As data is uploaded in the blockchain, organizations such as MSC, as an example, can keep track of the amount or volume of MSC certified fish along the supply chain. If too much MSC certified fish is sold in the market, MSC can check who is over-utilizing their accreditation, and hence guarantee that only MSC-labeled fish reach the consumer.

35 http://www.afr.com/technology/the-reality-of-blockchain-in-australia-lots-of-plans-but-waiting-for-the-big-hit-20170816-gxx6cs

Certificate authorities' credibility relies on their labels being used properly by verified farmers or producers. The ability to trace who uses the label, and preventing it from being double spent, is therefore key.
For instance, if a producer exclusively sells organic products, but only produces a third according to those standards, the producer is only given a limited quota of codes. If the producer tries to use the same code many times, the system will notice and challenge these claims.

Three areas of use for food

The result of this project is three identified main areas of applications which are interesting to investigate further and develop pilots and proof of concepts. These areas can be used together to realize the full benefit of the blockchain technology, but they can provide a lot of value independently as well.

The first area: Conditions at the production facility

Conditions at production sites are today difficult to verify and include labor conditions, in factories, environmental conditions, quality control in production etc. Responsible production of palm oil may for example be hard to control, especially since the ownership of the land is unknown. The blockchain could be used to make it very difficult to falsify or misrepresent conditions in production.

The current system is based on third party audits, but they have difficulties as described previous in the report (see page 16). A system with the blockchain could be made with:

A. self-reporting

Self-reporting is made with any digital records. A digital representation of the conditions such as a photo, video or a digital file can be stored at the production facility, or a mobile app. This could for example be a photo of a catch of fish or a factory. It could also be a list of people working at a factory. A verification of the same files, a digital fingerprint in the form of a hash, is published in a blockchain. Time and location cannot be manipulated since it is recorded in the blockchain. Outsiders then know that the digital file cannot be changed by the creator – but the creator does not have to share the content, i.e. the photo, the ledger for personnel, or the sensor information from the field etc. By making random inspections, an inspector can then verify that the photo corresponds to the actual conditions at the facility, the workforce, and that the outcome/production corresponds to the one reported to the blockchain.

B. continuous tracking of changes in the environment, production etc.

Reporting can also be automatic and continuous. If a sensor is continuously reporting for example temperature to the blockchain, history cannot be manipulated, and an inspection can check that the current conditions are not misrepresented. Humidity, temperature, light, pollution, water use or other quality indicators etc. can be tracked this way.

Benefits with the solution

The benefits with this solution is that it is very simple to set up and the cost is very low. There is little or no need for any integration with IT-systems at the production unit. A mobile app may take a photo of a factory or of a paper with a certificate of production, an auditor at the time of inspection etc. The data can be stored locally and privacy will then be very strong. The system focuses on the production conditions. The system will likely reduce the cost of third party audits, and the control of a third party becomes significantly easier.

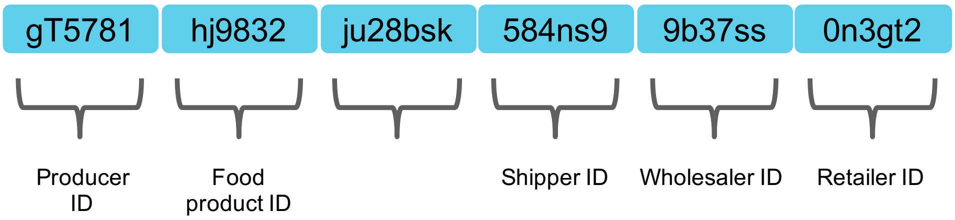
Weaknesses

The system requires the possibility to make random and unexpected inspections to realize the full potential. However, grassroot activities such as photos or random reporting can also work and can increase granularity and trust in the system. If there are many middlemen in the supply chain, the connection with the production can be lost if the product is not defined by a barcode or other product identification.

Tracking of food items in the supply chain

Blockchain technology enables possibilities to track a particular package of food, can or any item to which you can attach a unique identifier such as a barcode, QR-code, or an RfID transmitter. In this case it is particularly important that the registration of a transaction from, for example, a wholesaler to a retailer, is automatic and doesn't need manual work. Manual work would probably make the process too costly. Compared with existing technology, the blockchain can, but doesn't have to, reveal the identities behind each transaction. Integration with other data such as sensor data of temperature, humidity, certificates etc. can also be easier, and demand less costly integration. The cost and speed of implementation can probably benefit from an integration with existing product IDs such as the ones provided by GS1[36]. Jessie Baker at Provenance says that most of the providers use GS1 standards but GS1 doesn't let them add data to these standards, which limits applications somewhat.

Each product is assigned a product-ID by the producer. All organizations who handle this product, register their possession of the product[37]. An example of IDs that can be registered on a product is seen below.



36 GS1 is a not-for-profit provider of standards and identities for products, such as bar codes. They are frequently used for food all over the world.

37 In the Walmart and IBM case 6 out of 12 participants in the supply chain were using the system. Sometimes this can be enough. If it is a packaged product you can still track the barcode or the RfID tag for example.

The identification of the shipper behind the Shipper ID or the Wholesaler behind the Wholesaler ID can be encrypted. The owner or the controller of the keys corresponding to the code in the blockchain may not be disclosed to others than the previous and the following parties in the supply chain.

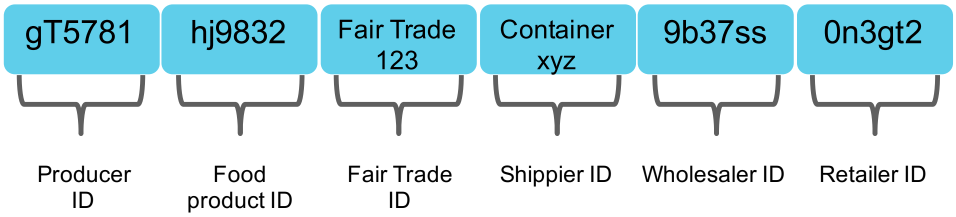
Within the blockchain the data may develop like this over time. At T1, there is a product registered by a producer who also registers a Fairtrade certificate. Each Fairtrade certificate is connected to a particular producer, and the Fairtrade monitoring organization can see if anyone creates too many products with respect to their quota. Outsiders may not understand this however. For them information on the shipper or the retailer for example is disguised. At T2 (found in the illustration below) a shipper registers the possession of the goods, again this can be disguised, or transparent if that is chosen. At T3 the wholesaler registers them as the organization in control of the product ID, and finally the retailer does the same (T4).

T4	gT5781	hj9832	ju28bsk	584ns9	9b37ss	0n3gt2
T3	gT5781	hj9832	ju28bsk	584ns9	9b37ss	
T2	gT5781	hj9832	ju28bsk	584ns9		
T1	gT5781	hj9832	ju28bsk			

Some of the information can also be made public

We are not only interested in disguising things but often want transparency, at least to some extent.

In the example below, the code that certifies that it is Fairtrade is visible in the blockchain. The actor in the supply chain who possesses a product may still be undisclosed. We simply know that this item has this label/certificate/quality etc.



Benefits with the solution

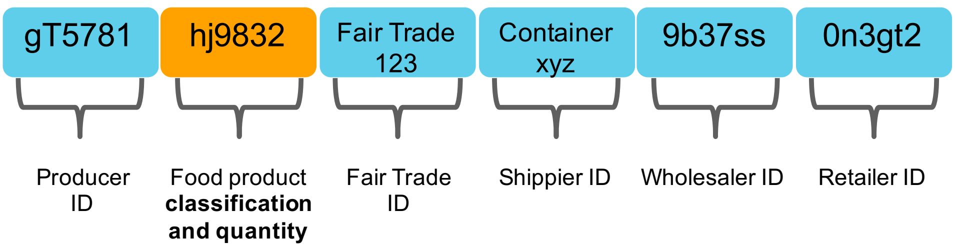
The benefit with this solution is that it has extremely high control. The risk of fraud becomes significantly smaller since the opportunity to double spend, i.e. sell a food product with high quality without a registered certificate, is impossible. The creation of unknown identities is not possible. The smart contract/application restricts the registration of new items for each user. As in the Walmart case, tracing back the product can be made very easily.

Weaknesses

The main weakness of the system is the installation and deployment cost. It is important to create an incentive to use the system. This could, as in the case with beef and fish, be made with regulation or with higher prices paid for better traceability by retailers and/or consumers. For less costly products, transaction costs will be important to handle.

Tracking of food volumes in the supply chain

While identification of individual grains, beans or oils like palmoil, olive oil etc. are difficult or impossible to track, it is possible to track the volumes bought and sold by each participant in a blockchain solution. The benefit from using the blockchain is that no central party needs to be trusted in getting all the data on transactions and volumes. With the blockchain, volumes produced of, for example organic soybeans, cannot be higher than the one bought for any party in the supply chain. If you buy ordinary rice in order to increase the volume of the more expensive basmati rice, and then try to sell the entire volume at the higher basmati rice price, you don't have enough units of basmati rice in the blockchain linked to your organization's private keys. Volumes cannot be increased in the blockchain. In this case we don't transfer a particular product-ID, but rather the product category and the volume. Since the incentive to manipulate the food is largely eliminated, a system that controls volumes but not individual food items will be sufficient to prevent fraud. Thus by tracking volumes, we then have a much better trust in the supply chain.



Benefits with the solution

The benefit with this solution is that we can handle situations where food is processed, cut, repackaged etc. If we control volumes, the incentive for fraud disappears almost entirely. If you cannot replace, dilute or blend the more sougth after i.e. expensive food item, it is difficult to make money from misrepresenting the food. It may also be possible to use alternative standards for representing the food, something that will be less of interest if the package already is classified with a standards system such as GS1.

Weaknesses

Traceability becomes somewhat weaker with this system compared to tracking the food ID. For a consumer or a restaurant that wants to trace down to farm level, where it originates from (merroir and terroir for example), or the time in transit or temperature, this can be more difficult to guarantee.

The Priorities going forward

The conclusion from this study is that the prospect for blockchain solutions within food traceability and control are substantial. A challenge is that the fragmented industry can make blockchain solutions difficult and time-consuming to implement.

Sweden is a small market from a global context and heavily dependent on international cooperation. Our ambition is to show the benefit of solutions in areas where we can add value within a few years. We have to develop solutions that either have a large value in the Swedish food supply chain alone, or are likely to be implemented or copied in other countries. With this in mind we, have identified two areas of special interest.

Tracking of volumes - Fish

Our fish is under pressure. More than 85 percent of the world's fish are under pressure or beyond their biological limits, and are in need of strict management plans to restore them. Many fishers are aware of the need to safeguard fish populations and the marine environment, however illegal fishing and other regulatory problems still exist..

To prevent further deterioration, legislators try to reduce the possibility to catch fish unlawfully. There is currently an EU-regulation with increasing demands on traceability of fish being caught in the EU, that is about to be implemented. The problem is that there seems to be no really good solution for this. Most countries have chosen to go with a paper based solution. Essentially, this means that each actor in the supply chain must keep a record of the previous and the following actor in the supply chain. They will to a large extent use paper based documents, because digital files can be manipulated if you don't use the blockchain. This system becomes very costly but protects privacy of the actors very well. On the other hand, the value of the solution may be limited because the public authorities have no overview of the amount of fish, and the possibility to act fraudulent is quite large.

The alternative has been to make a 100% transparent digital system. This means that all relevant information is sent to a public authority and stored in a database controlled by them. This puts privacy at a risk since the entire database can be stolen or tampered with. The personnel can also be blackmailed or bribed to reveal information to outsiders[38].

We believe there is a possibility to improve the system and reduce risk of fraud by using a blockchain. Everyone we have been talking to seem to share this opinion, even if the solution or the costs of a blockchain solution is unknown. Since a blockchain based system protects privacy, there is a possibility to make an EU-system that actually works across nations. Within the current system those few countries that have chosen to make a central database, will not be able to get foreign companies based in other countries to report to their national system to any large extent, we believe based on the interviews we have made.

A blockchain based system could also be expanded in many ways to enroll participants from other parts of the world. This would also more easily be expanded to the processed fish products and other food categories, which are not included in the existing EU requirements.

Transparency and control at the origin of production

The example described above, with control of the conditions at the production facility, is considered attractive due to the low cost and simplicity of implementation. We currently believe a solution with self-

38 In Sweden there can also be a problem with a law that permits all citizens to ask public authorities to access most public data.

reporting (alternative A on page 23) is preferred. Conditions that are to be represented are not yet identified but could include labor conditions, and production conditions, in the factory or in the field, and production inputs like the use of water, feed, pesticides, antibiotics, and more.

There are implementations of similar systems that are easier to manipulate in operation without the blockchain in Sweden. As an example, registration of conditions at the production site is found in restaurants and at construction sites, by requirement from the Swedish tax authorities. There is also stricter legislation demanding more control of conditions for employees for public sector purchasing contracts.

The proposed solution of control of food production with a blockchain would therefore serve as a means to comply with regulatory requirements, and at the same time, enable other valuable benefits like control of production inputs to be part of the blockchain at a lower cost.

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Christina Claughton-Wallin, **IBM**

Phil Harris, **Ripe**

Disclaimer

This report is a best guess and an effort to explain this very interesting technology and the future of food traceability and control. The report is a simplification of many things and may not be fully accurate in the eyes of the participants or the organizations they represent. No one takes responsibility for the content or the interpretations of the report. We look forward to learning more about the technology and its implications for society. Magnus Kempe is the author of the report. Carolina Sachs and Hanna Skoog are co-authors.

Appendix 1 The technology behind blockchains

In this part of the report, we will try to describe the basics of the technology. In the next part, we will describe the different blockchain technologies that can be used for food transparency and control. This part of the report is mostly found in a previous report The Land Registry in the blockchain – testbed from March 2017[39]. The project is a cooperation with the Swedish Land Registry, Telia Company, SBAB, Landshypotek Bank, ChromaWay, and Kairos Future.

A distributed list of fingerprints (verification records)

A central part of what is currently called blockchain technology is the ability to create unique verification records of digital files. For example, photos, transaction lists, registers, agreements, video films, patents, etc. Essentially, this includes everything that can be stored as a digital file.

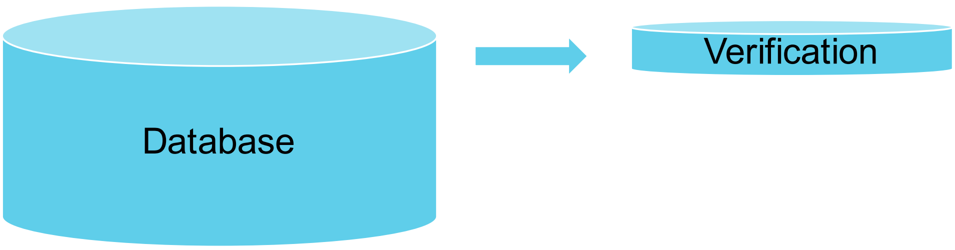
Using an advanced "fingerprint algorithm" any digital file can receive a unique code. This is technically called a cryptographic hash. An example of an algorithm that creates cryptographic hashes is SHA256. This algorithm takes all of the ones and zeros that describe a digital document and recalculates them in a repeatable but irreversible way.

An illustration of how an algorithm like SHA256 works is: take every third digit in the file, multiply the number by 7, and divide the total by every fourth number in the file. Combine every number not used in the previous calculation to the number you have, etc. In the end, a series of digits and/or letters is created, in other words, a hash. If the same digital documents and the same encryption algorithms are used, the result will be the same hash. However, it is not possible to understand what the file looked like that created the hash — it includes just a few characters, for example, 32 numbers and letters. In the same way that a fingerprint is

39 https://www.kairosfuture.com/publications/reports/the-land-registry-in-the-block-chain-testbed/

unique, the hash is unique for a digital file. But if you look at a fingerprint, you do not know what the person looks like, and in the same way a person looking at the hash does not know what the digital file looks like.
It is the verification records — the hashes — that are saved in the blockchain.

We can imagine that an individual government agency or organization may see an advantage in creating their own database of verification records. Different parts of the organization then can check the authenticity of documents and files by cross-referencing the list of verification records.



The owners of the agreements, documents, images, patents, etc. also benefit from having the list of verification records distributed to more stakeholders. A high level of redundancy reduces the danger of a single list of verification records disappearing. When multiple people have access to the verification file, the trust in that file grows. Everyone can therefore be confident that their document is considered authentic because multiple people have access to the verification records.

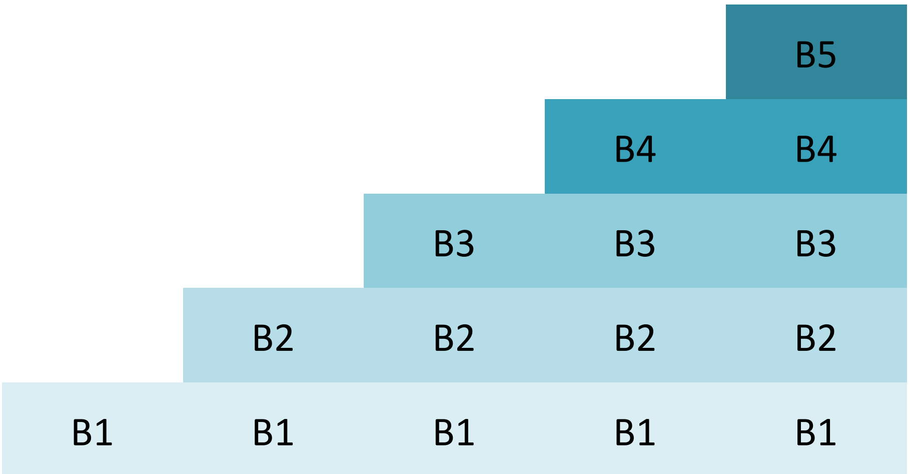
A fisherman who takes a photo of the catch can create a hash that is unique for that photo. If the hash is uploaded to an external database, a blockchain, the fisherman cannot manipulate the photo and still create the same hash.

The blockchain is a way of saving the list of verification records

Of course, there are large numbers of documents and large amounts of data that can benefit from having an external verification service. Therefore, one of the challenges is to be able to manage the large number of verification records/hashes. The blockchain is a way to save the hashes as a group in a list. A large number of hashes are saved as a group, i.e. a block. Each block with verification records is then distributed to the persons who have access to the blockchain, sometimes even publicly to anyone and everyone. The person who is in charge of approving which of the transactions should be saved and distributed in a blockchain, can do this more easily by grouping the hashes in a block. The alternative is to approve each hash one by one. In other words, it is not necessary to make blocks with many transactions, but the technology has the benefit of disseminating many verification records at the same time. In addition, something called a Merkle tree can be used to convert multiple hashes into one and therefore saves space in the block.

Blockchains are divided into different groups. The two main groups are open blockchains and private blockchains. In a private blockchain, there is one or a limited number of actors who approve the hashes that are to be saved in the blockchain, using digital signatures. For example, it could be a group of governmental agencies. In an open blockchain, practically anybody can approve the block according to predetermined rules. The largest open blockchain is the one that builds up the digital currency or cryptocurrency, Bitcoin. If the system and participants in an open blockchain accept the block, they start building on the next one.

The blockchain is called a blockchain because each block is linked back to the previous block. Each subsequent block gets a hash, i.e. verification, of the previous block, which makes it difficult to cheat by creating another version of what happened. For example, it is not possible to enter a new verification into an old block without changing the subsequent blocks. If a lot of people have saved the blockchain, they can see that changes have been made and that the manipulated blockchain is not correct.



In the case of the fisherman, this also gives an order in time for the photo of the catch. If the photo is uploaded in a blockchain, the photo cannot have been taken after the hash was recorded in the blockchain.

Who registers the block?

The blockchain and its verification records can be accessible to a large group of actors. The persons who approve which verification records will be added to the block, however, in practice are most often limited. In an open system, such as Bitcoin, the system is limited in that enormous numbers of fast processors and energy are required to win the right to approve the verifications in a block. In a restricted systems with a private blockchain, for example the system that NASDAQ launched as a trial for trading of unlisted stocks, NASDAQ themselves are the ones who approve the transaction lists and who gets to add transactions. In the case of NASDAQ, this is natural because this is the way they are working in their existing systems. On their exchanges, only persons with access to the trading system and who are connected to their exchanges can trade.

Blockchains can be a mix of private and public, and in these cases several actors can approve transactions but not just anybody. In the future, we can imagine that private organizations and groups of IT companies, banks, central banks and other agencies, will have blockchains that they monitor and regulate. While approval of the block is limited, access to the verification lists can be open, to all Swedish residents for example.

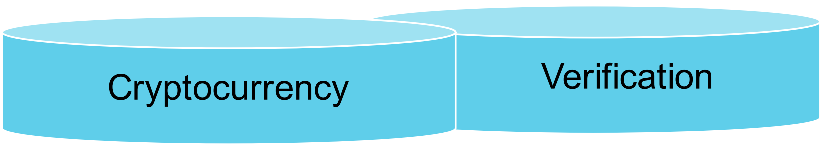
The power to approve the blocks

The advantage of having multiple actors who can approve the block is that the system is more transparent. The difficulty is to ensure that those people who contribute to the system by checking and approving transactions are doing it in the best interest of everyone, and they need some incentive to do this. In a government agency or at a bank or at a consortium, this isn't a major problem. The value of the service must naturally justify the investment due to greater security, increased transparency, efficiency, and revenues from the people who use the service, etc. In Bitcoin's blockchain, the incentive is determined by who provides the greatest security for the system. Those who contribute with the most energy and processing power also increase the system security the most. These are called miners - these are the persons and organizations that uncover codes that are needed to approve new blocks in the blockchain. By giving the power to approve the block to those who are contributing most to the security and speed of the system, the system ensures itself of a high level of security and processing power. Anyone who wants to take over the system needs to exceed the power of the other people who are maintaining the system. At the moment, their processing power in terms of hashing is far greater than the 1000 largest supercomputers in the world combined, and the processing power is increasing steadily as well. In practice, those people who are maintaining the system are not particularly interested in the power over the list of verification records since it doesn't do anything other than save the verifications and transactions but not the original documents. There are thousands of copies of the verification list so it cannot be changed without everybody noticing it. What those people who approve the block receive instead is a small payment from the verification records that are entered into the system.

Introduction of a digital currency

When Bitcoin was launched and the first block was created, it was practically free to add verification records. Still today it costs very little to register a verification record in Bitcoin's blockchain. Payment for the registration of the verification records is also important at the same time. If it had been free, the system would have had a harder time handling overloading of verifications. The problem with spam in the form of email depends in part on the fact that it is free to send.

In order to create an incentive for miners who would approve the block with verification records and ensure the security of the system, a digital currency, sometimes called a cryptocurrency, is awarded to them. The miners who dig up and approve blocks with verification records are paid by the system in the form of Bitcoin, which are digital codes that stay in the system. This system is programmed in such a way that Bitcoin is only created when a new block is created, and these are awarded to the person who identified the block and approved the verification records. Even private blockchains work in several cases with digital currencies as a part of the system. The hashes are actually entered as comment fields beside a digital currency or cryptocurrency.



The lottery determines who provides the approval

In the case of Bitcoin, an open lottery determines which computer or ”miner” wins Bitcoin as well as the registration fee for the verification records and therefore approves the next block. The system generates a number that all computers that want to can try to guess[40]. The person who has many computers and uses a lot of processing power and energy can guess many times and therefore has the greatest chance of guessing the series of digits correctly first. It is a little bit like a lottery. The person

40 This is a simplification of how it works. In reality each participants add a number and run SHA256 on the block with the number. If the result is a hash with a sufficiently low number the computer has proved it has spent energy on guessing and is rewarded with Bitocons and the transaction fees coming from the verifications that wants to be added to the blockchain. This is known as Proof of Work.

who purchases a lot of lottery tickets has a greater chance of winning. In the case of Bitcoin, the person who purchases many processors and use a lot of energy has the greatest chance of winning. In order to take over the system, you need to have as much processing power as possible so that you are sure to win the lottery many times in a row. Only then can the system be manipulated and controlled in a way that other people who are part of the system do not accept.

Cryptocurrencies remain in the system

An important point with cryptocurrencies in the blockchain is that these remain in the system. Cryptocurrencies can be transferred to another person as a code that can provide access to the cryptocurrency in the system. However, the cryptocurrency cannot leave the system. In other words, the person who owns a cryptocurrency owns an encryption code to an amount of an encrypted currency in a blockchain. If the cryptocurrency is transferred, someone else has access to the code that controls the currency. The word ”chain” is therefore particularly relevant for of cryptocurrencies. They are transferred like a chain from one owner to another, but the chain remains linked together.

Do cryptocurrencies have a value?

The idea of creating digital money is naturally something that has attracted many more or less serious actors. In our opinion Bitcoin is not fraud, but it can be used by fraudulent actors, like many other things including cash issued by central banks. Cryptocurrencies are sometimes fraud – it is something one should be very careful with. The recent hype around ICO's, Initial Coin Offerings, is very problematic. ICO's are intentional or unintentional fraud in most cases. Remember that this is not an opinion shared by all the participants in the project, and the opinions on the subject may change over time. For now, we strongly recommend people to stay away from ICOs.

The subject cryptocurrencies is related and interesting but the process for food should in most cases not be confused with the problems and possibilities with cryptocurrencies.

"Tokens" and Colored Coins

Regardless of whether cryptocurrencies are valuable in reducing transaction costs for international payments or whether they have value that can be saved and stored, they still have a value that has nothing to do with the function of money. Cryptocurrencies can store other information that is stored in the blockchain.

Digital currencies can, in certain cases like Bitcoin, be the carriers of information and agreements that are controlled by anyone that wants to ascribe value and information to them. The term "Colored Coin" refers to the ability to mark certain coins in a persistent way, to "color" them. The color follows transactions for a particular piece of cryptocurrency and provides the opportunity to give special meaning to a transaction chain of a set of cryptocurrencies.

We could think of colored coins being used for trading of CO2 emission certificates that can be traded. Within food we could potentially create a similar system where you trade rights to catch fish, use antibiotics etc. Organizations would then have to buy these rights in the form of a colored coin or colored digital unit of any kind.

Tracking (food) information

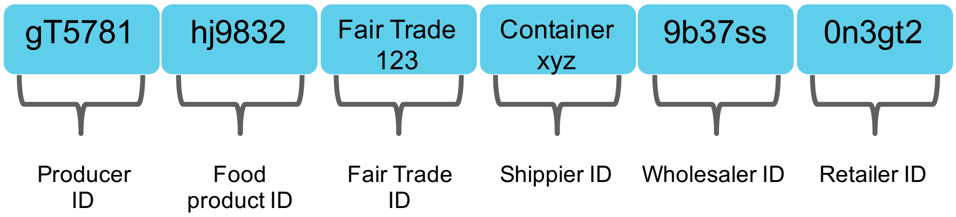
Except for digital units representing a unique currency or colored coin the units can simply be tracked in a supply chain. The units can be said to represent something that has no major value in itself but rather restricts that unit to appear twice in the system. One benefit with this is that there is less of a security concern. If someone steal a cryptocurrency or a digital asset that can be sold to someone else for other money and the righty owner of the asset has lost it (or the insurance company). In the case of food this is less of a problem. If someone steals a digital unit representing high quality certified Java Blue Mountain coffee beans, they have still not stolen the coffee. Recreating the files may therefore be possible for the holder of the proper coffee.

Another good thing for traceability is that we can be transparent with the information to some extent. We might write in clear writing in the blockchain that this represent a Fairtrade certified food product. Everyone in the value chain can then know this label is there, however it may not necessarily specify much more, we can disclose the food product, we can disclose whether it has been shipped or not, and the actors involved can be transparent, but they can also choose to be transparent.

The issuer of the Fairtrade certificates can keep track of all the transactions which are related to their labels/certificates. Therefore there is no risk of unknown Fairtrade certificates circulating.

In a private blockchain we may also add bigger files such as photos and documents to the blockchain. This is because a private blockchain can handle larger amounts of data. In a public blockchain such as Ethereum this will become expensive, and if a lot of people did this it would slow down the network.

These possibilities become a toolbox for tracking and tracing which is quite amazing and will continue to evolve over time.



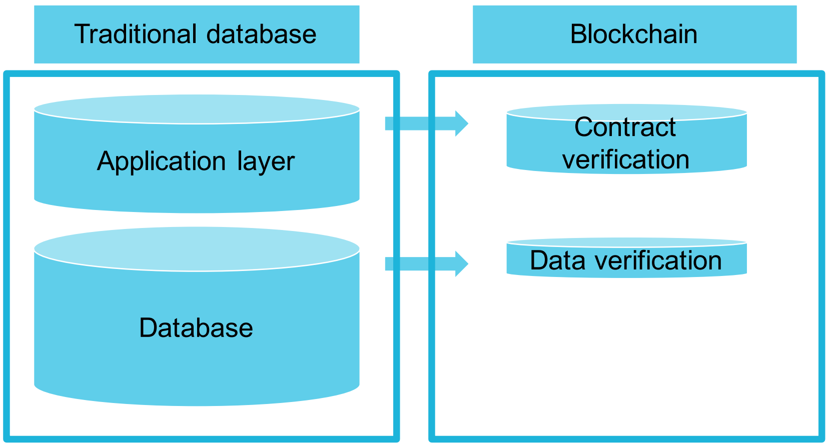
Smart contracts/ embedded contracts

As described above, colored coins are designed to allow a digital code in a blockchain to represent an asset. An even more interesting coding possibility is that we can add additional information that is stored in the blockchain that regulates, for example, data authorization and storage. In addition to separating the verification record from the traditional database structure, we can also separate parts of the application layer. Similar to hashes/verification records, only the person who owns or has programmed the coding and the rules for authorization and storage can interpret how the application works.

The system of adding logic and properties that are normally part of the application layer in an IT architecture has been called “smart contracts”. However, there are many different interpretations of what is meant by the term ”smart” in this context. Therefore, we also use the term ”embedded contracts” to highlight the feature that we are after. The logic is registered in, embedded, in the blockchain.

The cryptocurrency/system Ethereum was built with a focus on creating smart contracts/embedded contracts in the blockchain. Apart from Bitcoin, Ethereum is one of the current blockchains that is talked about most. Ethereum permits arbitrary code to be executed in Ethereum's blockchain as long as you pay for the number of cycles that is required to run the program.

Within food transparency and control, a smart contract could be set up to trigger warnings if a food product is managed incorrectly. When we talk about real-world events that can trigger events in the contract (for example the temperature is too high during transportation), we do not perceive these as acting independently but register the information in the blockchain. The contracts do not act autonomously based on real world events, but they can register the information. We do not know if such autonomous execution of contracts is technically secure today.

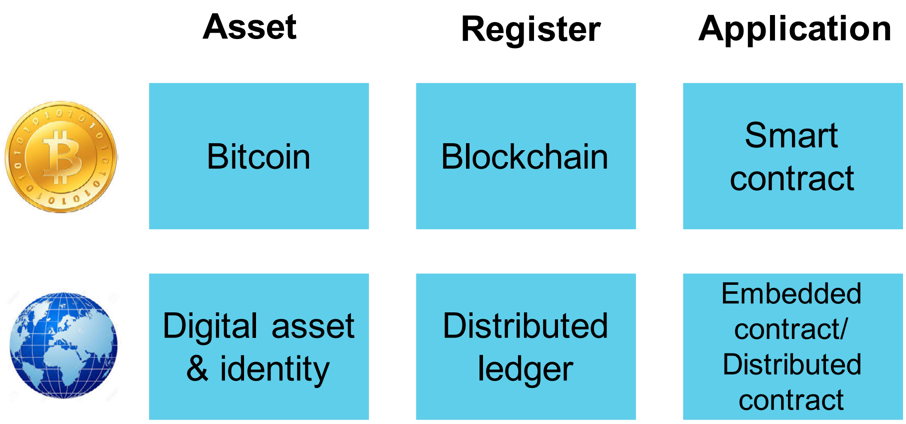


Overview of technology and use cases

The new possibilities can be understood through the example of Bitcoin and of more general use cases for the world.

The first widespread use case was for value storage and transfer, where Bitcoin made the new technological opportunities evident. In a more general interpretation this is understood as the creation of digital assets and digital identities, whether they are to be traded or not. One of the most well-known examples of this is the technology developed by Chain that is deployed by Nasdaq.

The second use case is a register where hashes of any digital entity can be recorded and verified. This was possible in Bitcoin and is possible in many other blockchains. A more generic interpretation of this use case is distributed ledgers. One application is the Estonian system built on technology by Guardtime.



The third use case is the smart contract, first described by Nick Szabo[41] before Bitcoin was released into the world. Ethereum, another major blockchain player, has focused on becoming a platform for creating and executing smart contracts. In the Swedish case with real estate transactions in the blockchain a technology developed by ChromaWay is used to enable smart contracts.

This is an overview of the three core functions of the technology. The examples on top is associated with Bitcoin (and Ethereum), and the ones at the bottom are more general applications.

41 http://firstmonday.org/ojs/index.php/fm/article/view/548/469%23Contracts

Appendix 2 Contributing organizations

Martin & Servera

The Martin & Servera Group is the leading restaurant and commercial catering specialist in Sweden. We are a Swedish family-owned group of companies. The companies in the group provide beverages, fresh produce, dry food, equipment and services to restaurants, cafés, bars and caterers throughout Sweden and Finland every day. The Martin & Servera Group consists of the following companies; Martin & Servera Sverige, Martin & Servera Logistik, Chipsters, Diskteknik, Fällmans Kött, Galatea, Grönsakshallen Sorunda and Martin & Servera Solutions.

Axfoundation

Axfoundation is an independent, non-profit organization that challenges, inspires, spreads knowledge and drives processes that lead to sustainable action and transformative change in society. We work with entrepreneurship as a driving force for change. We often collaborate with researchers, experts, decision-makers in Sweden and internationally in order to find long term solutions and new ideas. Our proximity to the many companies within the Axel Johnson Group gives us insight into the practical sustainability challenges with which the business sector is struggling.

SKL Kommentus

SKL Kommentus AB is owned by the Swedish Association of Local Authorities and Regions (SALAR) which is an employer's organization. Members of SALAR are 290 municipalities and 21 county councils/ regions. SKL Kommentus AB has two subsidiaries; Affärskoncept and SKL Kommentus Inköpscentral, SKI, (SKL Kommentus Central

Purchasing Body). The business is primarily focused on public procurement. Main activities are to carry out both coordinating contracts and individual contracts assignments for all local governments in Sweden.

The subsidiary SKL Kommentus Inköpscentral (SKI), is a purchasing group working with coordinated procurement. SKI offer all municipalities, county councils and regions and their companies to use the integrated framework agreement that are procured in own name. The goal is to make sustainable business for Swedish municipalities, county councils and regions, and hence SKI has a responsibility to provide framework agreements that promote sustainable development. SKI has a code of conduct that, among other things refers to ILO 8 core-conventions, UN human rights, anti-corruption that all suppliers to SKI have to fulfill.

Hållbarhetskollen

Since 2011, SKI offer customers follow-up, via audits, of ethical and social requirements through the service "Hållbarhetskollen". The aim is to promote that procured goods and services are produced under sustainable and responsible conditions, and this is done through follow-up in the supply chain of procured products. Hållbarhetskollen takes care of all planning of follow up actions, engaging auditors, publish audit reports and ensures that corrective actions will be performed by the suppliers.

The Swedish County Council Network on sustainable public procurement

There are 21 County Councils and Regions in Sweden, which are responsible for health care, dental care, and public transportation. Combined, the County Councils spend about 13 billion Euros annually on procurement. Many of the goods they purchase are produced in countries where there are risks of human rights abuses. Since 2010 all county councils have joined a national network and developed a common code of conduct for suppliers. The network also promote effective and efficient compliance monitoring. They also cooperate with SKL Kommentus.

Kairos Future

Kairos Future is an international consulting and analysis company that helps companies understand and shape their future. By analyzing trends and the world around them, as well as innovation and strategies, we help our customers see the big picture. Kairos Future was founded in 1993, our main office is in Stockholm, and international offices in Shanghai and Barcelona.