BLOCKCHAIN INTEGRATED SUPPLY CHAIN

Industrial Data and the Value Chain

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EXECUTIVE SUMMARY

Blockchain is poised to change the entire supply chain as we know it. The following document will demonstrate how all stakeholders in a supply chain transaction can benefit from adopting this technology, as well as how existing and novel industrial data can add unparalleled resolution and security to the value chain created.

This document will review:

- Blockchain fundamentals
- Blockchain advantages and smart contracts
- Supply chains
- How blockchain will benefit supply chain
- Integrating blockchain into supply / value chain
- Industrial data overview
- Why would you add industrial data into the blockchain?
- Adding data from industrial robot arms
- Adding data from PLC’s
- Quality control in manufacturing
- Connecting existing industrial systems (why and how?)
- Leveraging value from blockchain incorporated industrial data
- Benefits for small to medium businesses
- Some examples of businesses already integrating blockchain

This will provide insight as to how fundamental blockchain is for the progression of businesses in today's climate. Using this technology, Ascend Data Tech can help drive you and your innovations forward.

1. What is Blockchain

Blockchain is a revolutionary and important technology. It is unfortunately often associated with cryptocurrency. However, blockchain fundamentals are the foundation in which Cryptocurrency was built. But just as the internet was built as a military communication network at inception, we too are completely unaware of the implications and uses of blockchain in the future.

So, what is it? A blockchain is a method of transmitting and storing data in a way that makes it nearly impossible to change. It is a digital ledger that contains all transactions completed on the network since inception. These are stored in blocks which have programmatic methods of linking (or “chain”) them together, further adding to the security of the data.

There are many nodes inside of the network that participate in sending, storing, and agreeing upon the legitimacy of data, therefore making it a decentralized network. This digital ledger is duplicated across all nodes inside the decentralized network.

Blockchain entries into the ledger are also recorded using an immutable cryptographic signature called a hash.

A substantial benefit of blockchain technology is the ability to disallow, through design, the ability to tamper with current or previous data. Through consensus and Distributed Ledger Technology (DLT), a bad actor would need to change every block in the chain across all of the nodes in the system. This is extremely difficult and nearly impossible with enough nodes inside of the network.

A blockchain can be considered more secure with more nodes in the network. This allows for a greater population of nodes to operate in the consensus algorithms, and also provides further redundancy when the nodes themselves keep a record, or have access to, the distributed ledger.

Another benefit to blockchain technology, especially as it pertains to enterprise and industrial solutions, is something called Smart Contracts.

2. What Are Smart Contracts

Smart contracts are digital contracts stored on a blockchain that are automatically executed when predetermined terms and conditions are met. It is important to note that because these contracts are represented on the blockchain, it is practically impossible to break the contract, as all nodes in the network have access to the same data. This provides a zero trust network, in which all parties can be confident that the contract will be honoured.

Some benefits of smart contracts over classical contracts include:

- **Faster** transactions - from days to minutes
- **Fraction of the cost** - less administration / third parties and production output loss
- **Transparency** - contractual points are immutably stored, making scope creep impossible
- **Secure** - fully tamper proof and encrypted

Smart contracts do not need to be actual business contracts. In fact, they can be simple rules that are written to tell certain nodes in the network how they need to deal with one another. For example, you could have a smart contract that states that once a manufactured part is assembled and quality inspected by robots (each robot is a node in this instance), this component can be issued into the warehouse and stored.

The contract is now fulfilled and the series of parts, now all on the blockchain themselves, are removed from production and entered as stock in the warehouse. The next logical contract may be a purchase and ultimate shipment of a product to a customer. Even interbusiness smart contracts have their advantages as they allow for quick and efficient data transfer, and an immutable ledger that all parties (internal and external to the company) can agree upon.

3. Benefits of Blockchain

Blockchain technology has many benefits, some of which are:

- **Programmable** through the use of smart contracts
- **Distributed** through network design, adding to redundancy and zero trust
- **Immutable** in nature, the ledger cannot be changed without disagreeance in the network consensus
- Networks are **secure** by disallowing malicious data change through the DLT. All information is encrypted, adding a further level of security.

- **Anonymous** nodes are present on the network without offering their real identity. This allows for anonymity within the network (if required), mainly useful within a public blockchain.
- Through **consensus** algorithms all nodes must agree upon the information present in each current and past transaction
- **Time-stamped** entries allow for a chronological ledger throughout time. This becomes extremely important when integrating all data in a larger enterprise solution, especially one in a manufacturing environment.

Blockchain has a wide range of applications. Although many types of businesses can benefit from this technology, ranging from healthcare to government, for the purposes of this document we will be reviewing blockchain's potential in manufacturing and it's supply chain.

4. Supply Chains

A supply chain is the entire process of making and ultimately selling commercial goods to customers. This includes everything from raw materials and parts suppliers, to distribution and sales. A supply chain can become quite complex when many parties are involved, as once a product comprises many separate outsourced parts, an exponential amount of complexity arises.

In a standard supply chain system, as the number of stakeholders increases, so do the inefficiencies.

Some current inefficiencies in classical supply chains networks include:

- **Poor visibility** into the traceability involved within the supply chain. This means that when something goes wrong, such as a product failure or recall, it is at best extremely difficult to pinpoint the exact cause.
- **Disputes between stakeholders** can take days of administration, investigation, and negotiation due to incomplete, inaccurate, or untrustworthy data.
- Current supply chains often **do not track complete origins** of components involved during production. This allows for everything from sourcing unsustainable products, participating in illegal activities, and giving false information about the source of product for marketing purposes.
- Completion of **business contracts** are often muddled with inefficient use of time and processing. This invariably holds up every step of the supply chain, from shipping to receiving. This not only impacts consumers, but those reliant on their suppliers to produce their own products.

After highlighting only a few current issues with the supply chain as it is, let's investigate ways in which blockchain can help.

4.1 Common Supply Chain Components

Commonly, a supply chain includes, in chronological order from origin to consumer:

1) **Raw Materials**
    a) Materials from various locales
    b) Includes anything from crude ore from a mine to a finished part that will be assembled into another larger assembly
2) **Inbound Logistics**
    a) Logistics surrounding the shipping / receiving of the raw materials
3) **Goods in Warehouses**
    a) Supplier or third party warehouses store raw materials for customers
4) **Manufacturing**
    a) Manufacturing and production plants for finished products or parts for other suppliers
    b) This is where all parts and components come together
    c) Often many parts are needed to make a product. For example, a car can require an average of 30,000 parts
5) **Outbound Warehousing**
    a) Storage of finished products within the manufacturer's warehouse
6) **Outbound Logistics**
    a) Logistics behind storing finished products before reaching distribution / final destination.
7) **Consumer**
    a) Finished products reach the customer

Now that we have investigated an example of chronological operations regarding a supply chain and where blockchain could assist, it is worth examining where current attention is now, and where it could improve over the next few years.

5. Current Blockchain and Supply Chain Solutions

Blockchain's advantages are being leveraged to allow for transparency and trust amongst many involved in the supply chain. Current methods create a fabric of high-level information such as origin, ship / purchase date, price, status, etc.

Many improvements have been brought to fruition, and forward thinking companies are already integrating blockchain solutions to benefit stakeholders. This allows all parties in a vast supply chain to completely trust one another, creating substantial gains in efficiency. Much attention has rightfully been given to creating shared blockchains to allow for high-level information to be securely stored and shared. This creates an impeccably detailed image regarding where products came from, allows for fair and efficient trading, reduces regulator workload, and much more. It should be noted that this is still a nascent and new field, but much attention has been given to the above.

For the purposes of this document, only high level data points will be discussed, such as those captured in an Enterprise Resource Planning (ERP) solution. An ERP refers to a type of software that organizations use to manage day-to-day business activities such as accounting, procurement, project management, risk management, compliance, and supply chain operations.

Integration of blockchain technology into these components of business makes sense, and will provide immediate value and allow all stakeholders to see the apparent value. We believe that going forward, insight into low level industrial operations will be required to provide a **clearer image into the overall supply chain.**

Below is a list of data points paired with their benefits pertaining to industrial data and blockchain integration.

1) **Digitally capture, store, record, and verify processing data**
    a) Immutable and accurate data
    b) Pulled from the asset creating the data
2) **Capture quality testing data (text, images)**
    a) Can be captured on blockchain, offering all advantages reflected above
    b) Satisfies both internal and external quality requirements
3) **Track process inputs / outputs on the individual part level**
    a) Providing a clear image of entire production lifecycle
    b) Adds a layer of process and metadata that will ultimately become extremely useful in traceable, efficient, and value added production methods
4) **Track and record certifications**

    a) With the proper consensus and zero trust environment, manufacturers could self certify their products - while they are being manufactured
    b) Regulators could monitor transactions in live time through smart contracts
5) **Track production schedules linked to sales orders**
    a) Schedules can be linked in realtime to end of line devices completing the work (robotics or automated machinery)
    b) Internal tracking using blockchain ensures accurate inventory and status of all parts from production through to the customer
6) **Smart Contracts used to record sale / transactions**
    a) Self certification, traceability, and zero trust allows for autonomous completion of smart contracts. Since all stakeholders agree on the data, the completion of a business transaction can happen without user intervention

Blockchain can provide many advantages to supply chain, some of which are:

1) **Reduction in time, scope, and cost for recalls**
    a) All data is stored and therefore easily accessible
    b) Interested parties completely trust data
    c) No need for third party investigation
2) **Reducing disputes in quality assurance**
    a) All information is immutable and therefore cannot be changed
    b) Information can be put into blockchain directly from the device completing the work (described more later)
    c) Dispute resolution can be completed automatically through smart contracts
3) **Increased size of market based on assurance of quality**
    a) Manufacturers can better compete against others by utilizing their own blockchain integration as a supply chain value add
4) **Increase of price and value capture based on value for customers**
    a) Premiums can be paid from supplier to supplier when consumers pay a premium for traceability in products
5) **Distribution of value to stakeholders in the supply chain through smart contracts**
    a) Due to smart contracts programmatic nature, predetermined monetary incentives can be captured without any user intervention
    b) These can be pre-negotiated and may find their way into company and regulatory standardization (like taxes are now)
6) **Ability to connect to additional blockchain solutions such as insurance products and services**

a) As more businesses find the value in blockchain and it becomes more commonplace, there will be requests from new and existing customers to apply the same technology

7) **Meet increasing consumer demand for information of product origins**
    a) Provide direct value to consumers by allowing total insight into the production process, from raw materials to finished product
    b) Offers confidence to customers that information is factual

6. Industrial Data

In industrial automation, many data points are captured to provide input into machine operation metrics. These are often put into classic centralized databases, where information is utilized and displayed through Supervisory Control and Data Acquisition (SCADA) type software.

Data captured from machines can be used to make systems more efficient, less susceptible to downtime through preventative maintenance, more adaptive to changes in process, and all around smarter.

A movement has been driven ahead through what many are claiming is the current industrial revolution, Industry 4.0. Although hard to define completely, it is often said to be a time in which data and connectivity are able to make systems smarter through data analysis, artificial intelligence, and machine learning. Although blockchain is occasionally included in the definition of Industry 4.0, for the purposes of this document it is not.

Data is currently completed in a centralized method, using standard communication protocols such as MQTT and OPC-UA. This is assuming that any data was collected at all. Data is taken from the devices, often legacy in nature, using proprietary communication protocols, and is stored in a database such as SQL. Although this method works for most purposes, it is fundamentally lacking in the information and security required for effective supply chain / blockchain utilization.

7. Adding Blockchain to Industrial Systems

Industrial systems have a plethora of data, both direct and indirect, and this information will likely be required in developments related to Industry 4.0. However, it is recommended to consider using blockchain technology as the next logical step in a progression that may ultimately require it, through mandates and or simply good business practises.

It is proposed the benefits of blockchain, listed in detail above, be brought to **industrial networks.**

Industrial systems, such as automated machinery, Programmable Logic Controllers (PLC's), and robotic arms already have a lot of available data needed to add clarity to the supply chain picture. Only a small fraction of this data is even captured and or utilized in everyday processing. It will also be shown that properly added metadata can provide, with a low entry cost, extremely important contextual information that will provide even more value into the supply chain.

If these controllers and industrial devices also became nodes in the network, the consensus algorithm would become more accurate. This means not only will your enterprise data become detailed and valuable, your network will become more secure as a byproduct of these increased data points.

With custom technology connectors allowing industrial data to be captured, the specific supply chain and its associated data resolution can become orders of magnitudes more clear. It will be shown below how this can be done.

Next we will examine the industrial processes and see where opportunity lies. We will begin with the powerhouse of industrial production and product manufacturers, the industrial robot arm.

8. Integrating Industrial Systems - Robotic Arms

Industrial robot arms will be analyzed in more detail, as they are often the machines completing the physical action during the production process. They also have an extremely large amount of data that is accessible, and their programs can have metadata appended overtop of them to allow for a clearer supply chain image.

Industrial robot arms are often underutilized in this regard by many manufacturers as the initial priority when the robot was first implemented was the outcome of the process, not the coordination between the process and the supply chain. This data is

also often taken from intermediary devices such as PLC's, which only capture small amounts of the potential data present inside the robot controller.

Robots have many data points, and the hardware / software being run is typically tested more in depth by the manufacturer than custom solutions built by OEM's. This results in more reliable / useful data points. Robotic arm manufacturers have been refining their systems often for decades, whereas custom PLC controlled automated systems are often programmed and tested for a single application.

So what level of opportunity is there to pull data from robotics arms? The World Robotics 2021 Industrial Robots Report shows a record of 3 million industrial robots operating in factories around the world. Sales of new robots grew 0.5% despite the global pandemic, with 384,000 units shipped globally in 2020. Also, Global robot installations are expected to rebound strongly and grow by 13%, reaching 435,000 units in 2021.

8.1 Robotics - Internal Data

Industrial robot arms have an abundance of accessible data. They have the ability to report everything from motor temperature, total running time, maintenance schedules, alarms, etc. If this data was captured directly from the robot into an enterprise blockchain, there would be trust across all business units and external clients that the data from the robot has not been tampered with. Treating a robot controller as a node also allows for a more resolute and secure network.

A robot is often the lowest level element in a system and therefore one of the best representations of production and process data. It is also a capable computer with an incredible amount of internal data. The proposed technology connectors allow for the ability to access this data (immutably and securely), and incorporate this into the high level supply chain picture.

For example, consider you have an integrated blockchain technology installed in your factory. There is an alarm that keeps coming up on a robot, but it keeps getting reset on the robot controller by the operator of the machine.

In a classic system, this information could be tampered with, if it is stored at all (oftentimes it is not). Even on the robot controller itself, this alarm can be deleted.

With this information stored on the blockchain, that alarm and its history will always be there.

This is only one small demonstration of an issue that could be solved if an industrial robot arm or process became part of the enterprise blockchain solution. It is clear that having immutable storage of various robot data points would be advantageous. The internal data is also extremely accurate, and already operating on sophisticated hardware. This means that you can not only trust the data in the robot controller, but with the integration of blockchain technology, you can be sure of the data being stored and processed into the higher level software.

8.2 Robotics - Metadata

High-level information can also be captured in a zero trust network such as enterprise blockchain. Since the robotic arm is often the machine actually performing the work, (such as assembly or quality checks), it makes sense this information would be tied into the systems in place in a supply chain solution. Naturally, this information will be tied in using the form likely to be integrated in the future, which due to its apparent benefits - will be blockchain.

So why is adding in metadata advantageous to the supply chain / traceability of a blockchain solution?

If a robotic arm exists already, how would this information be added, without modifying a large portion of robot code?

8.3 Proposed Solution - Robotic Metadata Connector

With a simple custom plugin, metadata can be added to the robot programs to offer contextual data to the blockchain ledger being formed, allowing for greater value.

This could include the addition of “blocks or modules” that are assigned to certain sections of running code. With the right interface, it would be easy for the engineer to simply drag and drop a function onto the existing robot code to add in contextual data points.

This could include actions such as “when running this section of the program, remove X component from inventory” or “when this program completes, issue a part complete and pass this information onto the next robot in the process”. Each piece of code and metadata would have timestamps to ensure accurate process tracking.

This interface would be tailored to include information imperative to supply chain function, providing insights that wouldn't otherwise be available during the integration and commissioning of equipment.

8.4 Propose Solution - Automated Machinery Connectors

Going beyond robotics, one could imagine the level of information an automated system could provide. A robot should tie directly into the blockchain due to the advantages previously noted, but sometimes a piece of machinery is custom made, and is often run by a PLC. These can be thought of as the brains of a specific machine, and therefore there is a large amount of data and insight that can be gathered from a PLC.

Much like an industrial robot arm, large amounts of data points are present in a PLC, but are often not stored. In a world where the supply chain is completely transparent and free of third parties to inspect and regulate information, this lower level information will prove quite insightful.

Information that can be gathered from a PLC would include:

- Hardware fault status
- Safety status
- Production throughput
- Machine health
- An overall picture of the manufacturing process

Much like an industrial robot arm, a PLC can provide invaluable data to the supply chain. It is also proposed that a **custom connector will be built to communicate with PLC's directly, providing consensus at the device level**. This reduces latency between the PLC and the node connector, and allows for peer-to-peer (P2P) connectivity between machines and assets, sometimes called machine-to-machine (M2M) in the industry.

Connectors custom built for PLC's would provide another layer of depth, resulting in an increase in the value of the supply chain. Without these, industrial devices have classically been difficult to gather data from and put immutability into the blockchain.

Adding the connectors as close to the device level allows for many advantages, such as a reduction in latency, a higher amount of nodes for consensus, and improved accessibility for low level details.

The connectors are built to allow for easy additions of the metadata that allow for critical insights, much like the robotic arm concept discussed above.

9. Currently Stored Data - Not Reinventing the Wheel

It is apparent from the information presented so far, why a business may want to shift their data into the blockchain to gain the many benefits associated with this transition. The question is then not why they would shift over their data structure and network, but how (in the most seamless way possible)?

9.1 Proposed Solution - Industrial Data Connector

Much like the connectors that allow for blockchain integration discussed thus far, existing data systems can also be integrated.

The architecture would likely transition over two distinct phases, to minimize downtime and changeover energy. It is assumed here that a manufacturer in this example is using a centralized server to store data, and the communication protocol from the end of line devices is in a standard format (such as MQTT or OPC-UA).

So how could blockchain be integrated into a common industrial network, following a two phase approach?

1) The information that is currently being sent to a database, analyzed, and displayed on software will be mirrored and put into the blockchain.
    a) This allows for a manufacturer to make their transition to blockchain, without risking complete failure of an untested system.
    b) There is no impact to the current data, it is merely being replicated and stored into the blockchain. This would be using a custom connector.

2) A complete switch over to the blockchain ledger as the sole method of storing the data.
    a) This stage happens later, after internal testing is completed and the system(s) are determined to be consistent.

9.2 Existing Systems and Consensus

In an existing network of devices, it is often the case that the path of least resistance would be to keep the network the same, and to not add in nodes within the network at the device level (demonstrated above).

To account for this, the node logic and code **would run on computers within the network that already access this data.** This could include devices such as Human Machine Interfaces (HMI's), servers, and remote access computers.

The above architecture paired with device level nodes would allow for a more comprehensive network, but is not necessary to allow for all the benefits of blockchain.

10. Benefiting Manufacturers

So why does this matter to manufacturers?

To answer this, let's first define the difference between supply chain and value chain.

- **Supply chain** is the process between producing and distributing the product, dealing with the suppliers and logistics of getting the product to market
- **Value chain** is a set of activities carried out by the company, maximising the competitive advantage.

10.1 Value Chains - Leveraging Data

Traditional supply chains represent all the steps required to get the physical product to the customer. Modern value chains will grow the worth of raw materials by adding their digital twins and provenance data.

Instead of a status and linear representation, companies can provide customers, regulators, and internal business units with a textured and detailed description of the entire production process. Provenance can play a pivotal role as the world evolves toward a circular economy. Provenance is defined as "the place of origin or earliest known history of something".

Blockchain based provenance is not just the right thing to do, **it's good for business**. If the global business model shifts from shareholder profits to stakeholder benefits, then the accepted notion of value will change. Government policy makers will

incentivize corporations to act in a transparent way and collaborate openly with others, because that's what their voters want to see happen.

Much like how the gig economy, which is worth some 1 trillion dollars, was impacted by access and open standards, value chains can outperform supply chains as more industries provide truth into their actions, through both internal and external demand.

10.2 Small and Medium Businesses

In the United States, small and medium-sized enterprises (SMEs) generate half of all domestic jobs and 40% of its GDP. This may seem like a high number, but it is quite low in comparison to other countries. Australia is a key example of this, in which 98% of all businesses are SMEs.

These small and medium-sized enterprises are commonly finding it difficult to compete in the world market. Inefficiencies can cost a smaller organization more, as it can be a higher percentage of their profit margin on a product in comparison to larger companies.

SMEs are also less likely to have already gathered all their data into a stored centralized database, and have not yet fully transitioned into their own Industry 4.0 technology path. This, alongside the competitive advantages highlighted, make blockchain integration a very good choice for businesses of this size.

10.3 Examples of Blockchain Solutions

The following are examples of companies who have already integrated blockchain into their businesses:

- **FedEx** has integrated the blockchain into its chain of custody to improve traceability and provide a trustworthy record, helping to address customer disputes. The company has also joined the Blockchain in Transport Alliance (BiTA) and is a vocal advocate for the adoption of a blockchain-based industry standard.
- **DeBeers** is using the blockchain's tracking technology to monitor the source and progress of every single natural diamond they mine. In addition to improving efficiency and inventory control, the Tracr app also helps the company address consumer concerns about ethical sourcing of gemstones.

- **Walmart** has taken a serious interest in the blockchain, piloting multiple programs powered by Hyperledger Fabric. From tracing the origins of mangoes in the U.S. to tracking pork sold in its Chinese markets, the retail giant has embraced leveraging the blockchain to improve supply chain visibility and traceability — and capture more ethical and strategic sourcing opportunities while they're at it.

11. Summary

Blockchain allows for data security and transparency within a supply chain, allowing it to become a value chain. This offers greater value to all stakeholders involved. The immutable nature of the blockchain ledger allows for complete trust within the supply chain, reducing delays in administration, arbitration, and third party interventions.

Integrating blockchain is an important task for SMEs who want to remain ahead of their competition, as the traceability and its benefits will be requested by suppliers and consumers alike. With the use of smart contracts, business deals can also be completed automatically, whether between business units or across the value chain.

Through basic analysis, it becomes apparent that the benefits of blockchain will inevitably find its way into all aspects of the supply chain, with a large focus on manufacturers. This is especially true for those with many parties associated with their production process.

It is becoming realized that as more data is provided in high level integrations through blockchain, like those provided in an ERP system, the value of lower level data will become critically important.

Data at the machine level is vast, but only small portions of it makes it to the surface, if at all. Furthermore, these data points are not typically connected to the supply chain directly.

The leap from this disjointed and sparse data into blockchain is not far off. This is because a large portion of the data already exists within the machinery.

By providing hardware and software connectors to simply pull more contextualized data points from existing machine data, an immutable and completely trusted dataset can be established.

This data is often already pulled (or wanting to be) and stored, so the benefits are mutually inclusive.

Whether talking to specific assets or converting an existing SCADA system to communicate with a customer blockchain solution, connectors can be used to efficiently offer this service.

As technology advances and attention grows on the importance and functionality of blockchain technology, so too will the technology allowing connectivity to this new and innovative solution.

Until that time, we have the opportunity to connect the many millions of components on the market to help display the immediate value, clear up our muddled supply chain, add traceable insights, and continue progressing in other ways to help drive innovation within manufacturing, now with a little more trust.