CONNECTING FOOD

Can blockchain fix the food supply chain?

How the right technical approach will deliver resiliency, efficiency, and equity for the entire food system

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Introduction

Supply chain managers are under pressure to move goods efficiently, remove risk, and achieve total traceability from end to end, despite the complexity of a dynamic, distributed network of many different players. Distributed ledger technology (DLT), specifically blockchain, is touted as the solution to all our supply chain woes.

As blockchain adoption spreads, supply chain managers are learning what works and what doesn't for each **type of product**—virtual or physical, high price or high volume—and each **type of system**—vertically integrated or decentralized, digitally transforming or digitally native. Food supply chain leaders are expected to understand how to apply blockchain and all DLT-related concepts to our industry. The hype around this relatively new technology might outpace practical applications for traditional businesses like agriculture. Clearly, food harvesting and crypto mining are not the same.

With more differences than similarities between industries, it's often difficult to imagine how such high-tech tools apply to organic products. It's one thing to track a luxury watch around the world, but tracking a conventional potato from farm to fork feels extravagant at first glance.

Could blockchain be valuable **and viable** for the food supply chain? We're here to say yes.

The first widely-adopted blockchains indeed apply to cryptocurrency and other digital assets. But blockchain-based virtual systems can improve our world in very real and tangible ways. The full potential is just starting to become apparent. And it goes well beyond crypto.

There are four technical concepts that, when looked at individually, help paint a clearer picture of how blockchain will shape the future of the food supply chain:

- digital twins as tokens
- efficient validation protocols
- variable permissions
- neutral governance

Taken together, these strategies have the potential to create an entirely **new economic model** for the food system.

Let's set the table.

Blockchain

Most supply chain professionals generally understand that DLT offers a new level of security and reliability. In a traditional database, data can be modified or deleted relatively easily. In a blockchain database, thanks to cryptography and relationships between data sets, data is effectively permanent.

"Every record, or set of records, added to the ledger represents a block of data. Every block links to the previous block by including a cryptographic hash, a timestamp and transaction metadata. Thus, every block connects to form a growing "chain" of blocks — deriving the term blockchain — to create secure and immutable records. A record cannot change without altering the cryptographic hash — as well as all hashes in subsequent blocks."[1]

Cryptographic hashes cannot be reverse-engineered, and if data is tampered with, the blockchain breaks. For someone to alter data, they must simultaneously edit it in many different places. With all records redundant and distributed, there's no single point of failure.

So far, so good.

Transactions

Transactions are a type of record well suited for blockchain. With blockchain keeping a permanent, immutable record available to anyone with the right permissions, **no intermediaries** and **no trust** are necessary for the system to remain intact as it grows. Trust is nice, but it limits a system's size, scope, and reliability to only what can be managed through human relationships.

> *Blockchain will do for trusted transactions what the internet did for communications.*
>
> GINNI ROMETTY, CEO OF IBM[2]

Each transaction triggers a request to write a new dataset to the blockchain. All nodes on the blockchain receive the transaction details, check hashes, and perform a process to prove the transaction is valid. (The predominant consensus method is proof of work, but a more efficient approach could apply when handling very high volumes of transactions. More on this later.) If the nodes validate the transaction, it permanently joins the chain.

[1] *Blockchain: An immutable ledger to replace the database*
[2] *IBM's CEO on how blockchain will change the world*

What are we trading?

Tokens

Each transaction has a sender, a receiver, and something exchanged. On a blockchain, this "something" is represented by a token.

Tokens are representations of an object: currency, content, or physical entity. Let's look at some examples of digital tokens stored on a blockchain.

TOKENS

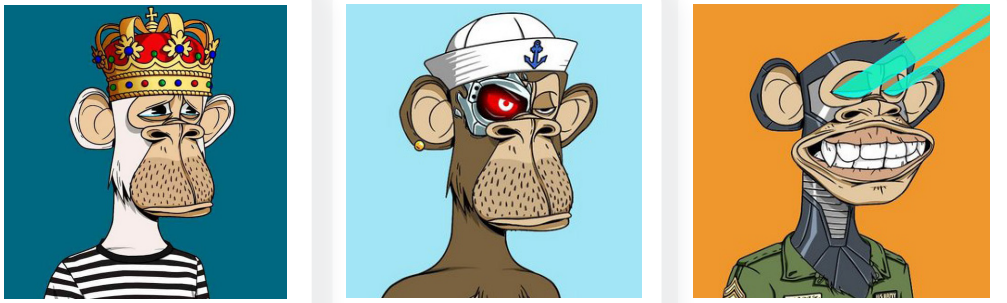
Cryptocurrency	NFTs	Digital Twins
Bitcoin	Music NFTs	Digital Twins of Environments, Cities, Buildings
Ethereum	Art NFTs	Digital Twins of Manufactured Goods, Automotives, Electronics
Tether	Video Game NFTs	Digital Twins of Food ("Food Twins")
+10,000 other active currencies	Domain Name NFTs	
	+ proof of ownership of anything	

Crypto

Cryptocurrency is the most widely-known type of token. Popular cryptos are bitcoin and ether, but there are over 10,000 active cryptocurrencies as of early 2022. A cryptocurrency exchange like Coinbase or Binance facilitates trades, and the blockchain stores information about owners and transaction histories. These simple tokens are essentially commodities. One token is always equal to another of the same currency.

NFTs

Non-fungible tokens (NFTs) are up-and-coming. They make headlines when celebrities create and sell NFTs, essentially digital works of art, for vast sums of money. Beauty is in the eye of the beholder; we don't judge.



Bored Ape NFTs on the Ethereum blockchain

An NFT is a digital asset. It could be something as immersive as a virtual reality experience or as simple as a PDF. NFTs are **unique**—even if they are replicated. Consider a run of 100 limited-edition physical prints of a work of art: each is one-of-a-kind, although there are 99 others just like it. Replication will impact the value of each, of course.

NFTs have wide applications beyond art. Consider digital records of a patent, a website domain, a deed to real estate, or the recipe for Coca-Cola. These assets can be shared with authorized users—without necessarily granting ownership. You can share your digital medical record with your doctor, but it's still yours. (This idea will be important to recall when we look at monetization in the food supply chain of the future.)

Such assets can also be held, secured, and traded, just like crypto can be bought and sold, except that each is unique. No matter your taste in music, an NFT song by Madonna is not equal to an NFT song by Snoop Dogg.

An NFT exchange contains information about the owner, transaction history, **and unique metadata** about the content. Note that NFTs are a step up in complexity from cryptocurrency.

But let's go further.

Digital Twins

A digital twin is the virtual representation of a physical object. It offers much more information about an asset than what you can see with the naked eye.

While the idea of an NFT was derived only in the last decade[3], digital twins have been around for more than half a century. In 1970, NASA famously used a primitive form of a digital twin on a space rescue mission.[4]

Digital twins are a well-established, mature technology. They are used universally in design, engineering, and manufacturing processes to model the performance of a system under various conditions. Sensors, RFID, and other Internet of Things (IoT) technology can feed real-time data from the real world back into the virtual world. In this way, digital twins can remain accurate representations of their physical counterparts. Plus, the larger system they are a part of can continuously learn and improve its predictive models based on real-world inputs.

But digital twins won't be trapped forever in their original realms. Digital twins are moving beyond engineering, manufacturing, and IoT domains—and onto the blockchain.

> *Anything of value can be tokenised to be traded, including physical assets (with a digital twin to link digital to physical).*
>
> ANDY MARTIN[5]

A robust digital twin of a unique physical object offers a whole new dimension of data and, therefore, new possibilities for a blockchain-based system to connect the dots and deliver value.

Let's look at a non-food example first.

[3] *A Brief History of NFT Art*
[4] *The Mysterious History of Digital Twin Technology and Who Created It*
[5] *The Token Economy, Andy Martin*

NFTs vs. Digital Twins:

An automotive example illustrates how their applications on a blockchain can differ.

An **NFT of a car title** can contain the make, model, year and classification, the owner's name and address, and vehicle identification number. Let's consider a hypothetical Car Title NFT Exchange. This fully populated NFT Exchange would track the transaction history of titles and information about all prior owners.

If there were a dispute about who's car is double-parked outside the police station, a blockchain of title NFTs offers an immediate, accurate answer.

But, let's say we've populated our Exchange with NFTs representing car titles from California, Kentucky, France, the UK, and China. The data and data formats within each title NFT are different. Some may give us greenhouse gas emissions; others won't. Some will offer accident reports; others won't. Language translations and unit conversions are necessary.

Non-standard data limits any automated analysis. Large-scale queries are impractical. So NFTs are helpful for some traceability use cases, but not all.

A digital twin of a car, while historically used for engineering and testing purposes, can also be tokenized on the blockchain. This digital twin can contain the unique vehicle and ownership metadata, the digital model of the vehicle from the designer, and all serial numbers and parts information from the manufacturers—down to the lifespan of the LED bulbs in the headlights.

On a hypothetical Digital Twin of Cars Exchange, the blockchain records how tokenized digital twins, and their physical counterparts, move through a supply chain. Now we can program algorithms to answer more complex questions.

Suppose a risk manager discovers that the fabric used in a batch of 10,000 airbags was compromised. Who currently owns all the cars affected around the world? Who previously owned them? A blockchain of digital twins of cars can produce an accurate list in seconds because standardized digital records (such as those that comprise digital twins) are queryable.

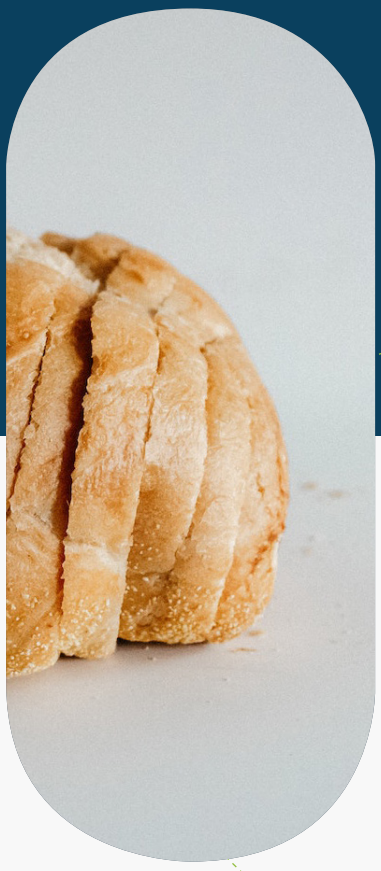
The digital twin token is **transferable** (like crypto), **unique** (like NFTs), *and* **standardized.**

Can anything be digitally twinned?

In theory, yes, anything can be represented by a digital twin. Replicas of any physical object, no matter how small or insignificant it is by itself, can be stored securely, tracked with precision, and exchanged autonomously on the blockchain. This level of granularity is part of the vision for a digitized supply chain—the meta supply chain[6]—enabled by Web3 trends.

In practice, the more complex, mechanical, high-value products and systems tend to get digital twins because of the effort required to generate them. The cost of populating a blockchain full of digital twins must be less than the value gained from it. Therefore, the goal of any supply chain is to create comprehensive, accurate digital twins as efficiently as possible.

Stay with us. This is big.



[6] *Look out supply chain—Here comes the Metaverse*

Presenting **Food Twins:** Digital Twins of Food

Food is organic matter and a highly unique product category when it comes to the modern supply chain. A digital twin of food (a **food twin**) represents everything there is to know about an edible product or raw ingredient:

- Who produced it, when, and where
- How it was produced, with what fertilizer, feed, or treatments
- How much water and energy was used in its production
- If the producer pays its workers a fair wage
- If the cold chain was broken, where, and when
- Where, when, and how it was combined with other ingredients
- Where, and when it came in contact with any contaminants
- Its total carbon footprint

... and more.

This data tells a food product's full story, and the story is what gives it value. Consider two apples that look identical. If a consumer knows one was grown on an organic farm nearby, they will choose it and pay more for it.

With food twins on a blockchain, buyers can see the immutable record of this information and will not have to depend on a seller for the story. They can know, without a doubt, the food's origin, carbon footprint, validated certifications, and any other attribute.

A food twin carries primary evidence of the story we're accustomed to getting in pieces from other parties along the supply chain. For supply chain managers, a food twin on the blockchain contains the food's physical attributes, history, ownership, and where it is in the supply chain at any given moment.

Plus, just as real food is processed and transformed to create new products, food twins can be split, combined, and transformed to create new food twins (something that is impossible with NFTs). A food twin of a finished product can hold all food twins of its ingredients.

Food twins capture the true dynamic nature of food as a product more accurately and with more depth than any other flat digital representation.

The ingredients of a Food Confidence Platform

Now we can agree on these basic assumptions:

- The blockchain is ideal for automatically tracking the permanent record of transactions, especially within a complex supply chain.
- Food twins are the ideal type of token to represent how food is produced, handled, processed, and transformed.

When a blockchain is infused with food twins, the result is what we call a **Food Confidence Platform.**

A Food Confidence Platform automatically **audits, tracks**, and **reports** on food products within the supply chain in real-time. It offers true end-to-end traceability and unmatched transparency.

To be clear, this is a surface-level description of such a powerful new concept. The configuration of the technology stack that supports a Food Confidence Platform has major implications for its success. Critical structural decisions determine a system's ability to impact the entire supply chain, improve safety and quality, and withstand increasing complexity.

So, let's look behind the curtain and ask the hard questions.

Is a Food Confidence Platform practical? And scalable?

High-volume food twin generation

Generating the data necessary for comprehensive digital twins is challenging on two levels:

1. Much of the information originates offline, not in cyberspace like cryptocurrency, and must be digitized somehow.

2. Much of the information originates from traditionally low-tech and low-margin operations: farms and slaughterhouses.

The only way to sufficiently lower the barrier of entry and infuse a system with adequate data is to generate food twins **autonomously**. Look for apps that can read already-installed ERP systems or accept batches of raw data in .csv format. (For example, the Food Twin Generator and LiveAudit applications on the Connecting Food platform automatically generate food twins for practical use downstream.)

The winning approach will allow primary producers to contribute source data to food twins in a completely hands-off manner without requiring a new system or process change.

Dealing with real-world, non-sequential data

Because digital transformation efforts are still underway in the food system, particularly for upstream players, source data is often disorderly and delayed, if it's shared at all. Plus, the food supply chain is particularly complex and decentralized compared to manufactured goods, meaning data is siloed and not accessible in real-time. As a result, source data for food twins and transactions may be offered out of sequence.

Disorganized data is rampant in food supply chain transactions. Strategic infrastructure and protocol decisions can elegantly address this reality.

You'll recall that records on a distributed ledger are immutable: participants can't easily add or change details discovered after the fact. This challenge can be solved by a buffer system that organizes and validates data before writing it to the blockchain. (At Connecting Food, we take data from the Food Twin Generator and LiveTrack applications, reconcile the transactions, and run it through our data pipeline.)

Many supply chain technologists struggle with writing messy real-world data consecutively. A **proof-of-elapsed-time** validation protocol is a particularly innovative way to address the challenge of processing information that is received out of sequence[7].

[7] *Proof-of-elapsed-time is supported by the Hyperledger Sawtooth platform*

A sustainable approach to a data explosion

Climate change poses an existential threat to food production. The entire agribusiness ecosystem must prioritize sustainability in all decisions—including technology.

Some blockchain applications have received backlash for being energy-intensive and environmentally costly[8]. Is there a responsible way to populate a blockchain with digital assets at the scale of the global food system?

"Web3 will continue to require a network of mining nodes to power the blockchain," per Boston Consulting Group in The Corporate Hitchhiker's Guide to the Metaverse. However, an infinite expansion of traditional, energy-intensive IT infrastructure won't be necessary, in part because of "the shift in most major Layer 1 blockchains from the proof-of-work consensus mechanism (which requires expensive mining hardware and electricity) to more efficient computing mechanisms such as the proof-of-stake mechanism (which greatly reduces these requirements)."[9]

The proof-of-elapsed-time mechanism is similarly more **energy efficient**, operating more like a lottery. The node with "the shortest amount of time is elected to do the block mining that round. The system tends to be fair and choose miners with a good degree of randomness. It doesn't require much electricity consumption."[10]

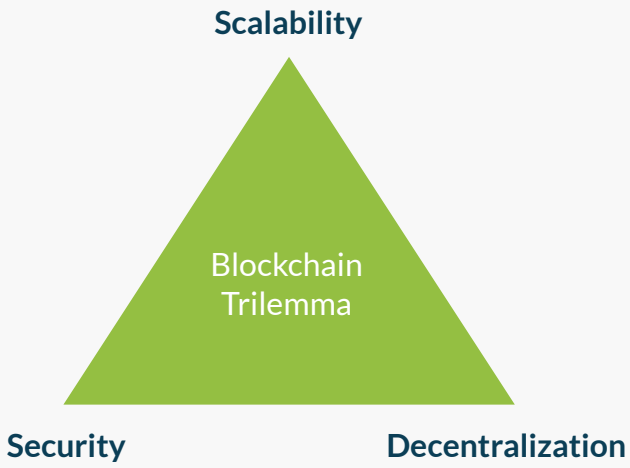
[8] *How Much Energy It Takes To Power Bitcoin*
[9] *A Corporate's Guide to the Metaverse, Boston Consulting Group*
[10] *What's Proof of Elapsed Time?*

Is a Food Confidence Platform secure? And equitable?

The Trilemma

Blockchain network designers must make strategic trade-offs between scalability, decentralization, and security. This is known as the Blockchain Trilemma.

- **Scalability:** the speed and volume of transactions
- **Decentralization:** the distribution of network nodes
- **Security:** the integrity of the system from compromise[11]



Most B2B blockchain platforms tip the scale toward security, favoring the protection of IP and trade secrets over anything else.

Food processors and manufacturers must protect the industrial processes they have refined and perfected over decades. Brands must protect their secret recipes.

Luckily, with a permissioned blockchain, competitive differentiators can remain secure while other datasets can be read and published via consumer-facing applications. (LiveScan on the Connecting Food platform is an example of how brands can closely manage what kind of information is accessible to downstream buyers and consumers without compromising transparency.)

[11] *Cryptopedia | Gemini*

Governance Strategies

Consortium-led

Permissioned blockchains can be controlled in several different ways. A blockchain can be established and heavily governed by a **consortium** of people or entities who set up the rules of engagement. IBM Food Trust and Aura Luxury Blockchain are examples of consortium-led blockchains.

Some would-be participants may be excluded if they don't meet the standards set forth by the governing class. Consortium rules may mandate requirements such as implementing new processes, adopting an expensive new system, or adhering to ever-changing quality certifications.

Platform-based

An alternative approach to permissioned blockchains is to deploy an inherently neutral **platform**, not a system subjectively guided by companies with vested interests.

A decentralized autonomous organization **(DAO)** governs through a transparent set of rules. This approach can offer a much lower barrier of entry, allowing for more transparency into more products and shedding light on the entire supply chain.

Consider the alternatives. Suppose a consortium rule prohibits a supplier from participating in a virtual exchange because of the effort to change their processes, cost to join, or quality standards. The resulting network will inevitably represent only a percentage of the global food system. If every player can join, the entire system gets closer to full transparency.

An indiscriminate and transparent system enables buyers to purchase any product, for example, a cheap chocolate bar, with a clear understanding of how it was produced at such a low cost. (Was it the origin of raw materials, labor practices, or other processing shortcuts?) With eyes wide open, the market and policymakers can decide what business practices they will allow.

The long game: a new economy?

We could stop there, and it would all be very exciting and efficient: Algorithms are executing transactions and spontaneously generating food twins… Time-consuming, non-value-add processes are a thing of the past… Distributed ledgers keep a permanent record of asset ownership, identity, and access… Upstream and downstream data are in sync… DAOs manage the growth of networks automatically… The infrastructure is sustainable… The food system is secure… Recalls are highly targeted—or prevented entirely… Sustainability metrics are at your fingertips… It's the supply chain manager's dream!

If we take this base and extend the logic of tokenization and economics, it gets even wilder. Within a decade, a new economic model emerges to equitably and sustainably redistribute value across the food supply chain.

"As the metaverse grows in popularity, virtual assets will gain in economic value, and a growing number will be created by individual users and exchanged between users and companies. These assets will be owned either in Web3 decentralized infrastructures or in 'walled gardens.'… Their transaction value will range between $150 billion and $300 billion by 2025."[12]

Tokens represent anything of value. When consumers choose a food product, they decide between origin, production method, energy consumption, price, and more. With tokens, network participants can incentivize consumers to modify their choices. For example, a consumer can earn points (or credits, crypto, etc.) for purchasing a more sustainable option.

Many businesses already employ this strategy to increase engagement and influence behavior. Accumulating miles on an airline encourages loyalty to that brand. Brands from Waze to Nike to Starbucks all grant points to consumers for performing specific actions.

While the basic concept is not new, Web3 technology allows for a new level of ownership outside of privately managed platforms. Tokens can be stored in a digital wallet on the blockchain, accumulated, and redeemed for real value. Consumers may even transfer tokens to another network participant, for example, to "tip" their producers or "vote" for a new product.

Companies can use tokens to reward consumers for certain choices, or to gamify the experience.

[12] *A Corporate's Guide to the Metaverse, Boston Consulting Group*

Implications of a successful Food Confidence Platform

Consumer Confidence

Consumers stand to gain a lot in this new reality. A Food Confidence Platform offers shoppers visibility into the source and nature of their food, influence over the attributes they wish to see on their tables, and participation in new value chains. They also benefit from a supply chain that is better equipped to prevent contaminated food from advancing downstream to retailers.

Producer Power

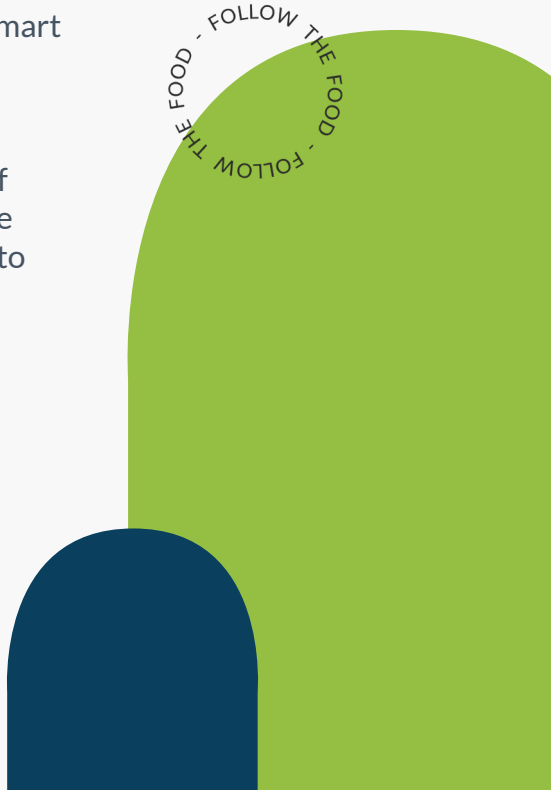
For primary producers, a Food Confidence Platform offers the opportunity to be more visible to consumers and an opportunity to monetize food data. Food twins tokenized on a blockchain can be exchanged in parallel to their physical counterparts with the right platform capabilities.

As farmers exchange both the ownership of physical food *and* the rights to use the digitized information about the goods, new opportunities emerge. Producers can be paid fairly for the data generated automatically from their labors. Much like a musician earns royalties from music streaming services for each track played, a farmer can earn compensation for the information in demand: the origin story of hero ingredients.

Collaboration

Data within a food twin is generated collaboratively by all the players in the supply chain. Each contributor can retain ownership of their original data, even while sharing access with authorized users. Smart contracts can execute both the transfer of ownership of physical goods and access to data.

Such ownership and monetization encourage the proliferation of food twins, which feeds the meta supply chain and renders all the benefits that come with it. A neutral platform with a low barrier to entry ensures that the whole system is represented.



Try the world's first Food Confidence Platform.

With digital twins of food on a blockchain, Connecting Food has created a groundbreaking system for virtualizing the food supply chain while providing immediate business value.

Connecting Food's portfolio of integrated applications spontaneously generates food twins at the farm, audits in real-time, follows the food, and lays the foundation for a transparent food system.

LiveAudit
LiveTrack
LiveScan
FreshOrigin
Food Twin **Generator**
free for primary producers
Food Twin **Exchange**
CSR **Analyzer**

These easy-to-use agribusiness tools offer:

- end-to-end, real-time, batch-level traceability
- painless digitization and standardization of data
- 30-day deployment
- immediate operational efficienciest
- unfettered internal visibility
- improved consumer confidence

> *Connecting Food is for agribusinesses seeking to be more transparent.Their platform goes beyond blockchain, beyond technology. The transparency gained helps our entire organization focus on core business objectives.*
>
> REGIS LE THIEC, CIO
> AXEREAL

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