Blockchain's Smart Contracts: Driving the Next Wave of Innovation Across Manufacturing Value Chains

Smart contracts with embedded business rules promise not only to reduce transaction costs but to create more agile value chains that enable closer cooperation and enhanced trust across the extended manufacturing ecosystem.

Executive Summary

Blockchain – the cryptocurrency technology with the potential to eliminate financial services intermediaries – may also have the power to fundamentally change the manufacturing industry as we know it. By allowing supply chain partners to create trusted relationships without the need for banks or, perhaps, even traditional purchasing processes, manufacturers, suppliers, customers and machines can find each other and do business much more quickly and inexpensively.

Even more importantly, they will be able to form more agile supply chains through "smart contracts" that automatically find, negotiate with and close deals with partners the world over. This will help all participants across the value chain to speed new products to market that meet ever-changing business needs, and will enable more trusted and fruitful relationships.

But leveraging blockchain will require carefully balancing risks versus benefits, integrating new technologies and processes with legacy systems and evaluating the maturity of the required technologies, standards and providers. It will also require overcoming resistance from both government and established intermediaries such as banks.

This white paper explains blockchain, what it means for the manufacturing industry and how to begin using it to drive quantum leaps in efficiency, agility and innovation.

Blockchain Explained

Blockchain is a software mechanism, now primarily known in the form of bitcoin in the financial services world, that provides a distributed system of trusted assets and transactions without the need for a central trust authority.

For manufacturers and their suppliers or logistic partners, an individual transaction in a block might contain bills of lading for raw materials or finished goods, proof of the origin, quality or operations performed on a part or instructions for the place and time of a delivery. In each case, the information could be stored, trusted, shared and changed by the partners without going to the cost, expense and delay of negotiating formal contracts or paperwork such as letters of credit from a bank or a bond for a transportation provider.

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Unlike in a traditional supply chain, where these documents and contracts are maintained by each partner's purchasing, accounting or legal department, in a blockchain these elements are stored on many decentralized nodes. Their privacy and integrity is maintained by "miner-accountants" rather than by a counterparty or a third party such as a bank (see Figure 1).

Blockchain enables the creation of smart contracts, with terms and conditions both sides can specify and that assure trust in the enforceability of the contract and the identity of the counterparty. This system of distributed trust allows for lower transaction costs in the short term, but this

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How Blockchain Works

A distributed database running on multiple servers continually checks the security and integrity of each transaction or data entry. Blocks chained by hash values and incentivized proof of work provide a foundation for distributed trust in blockchain.

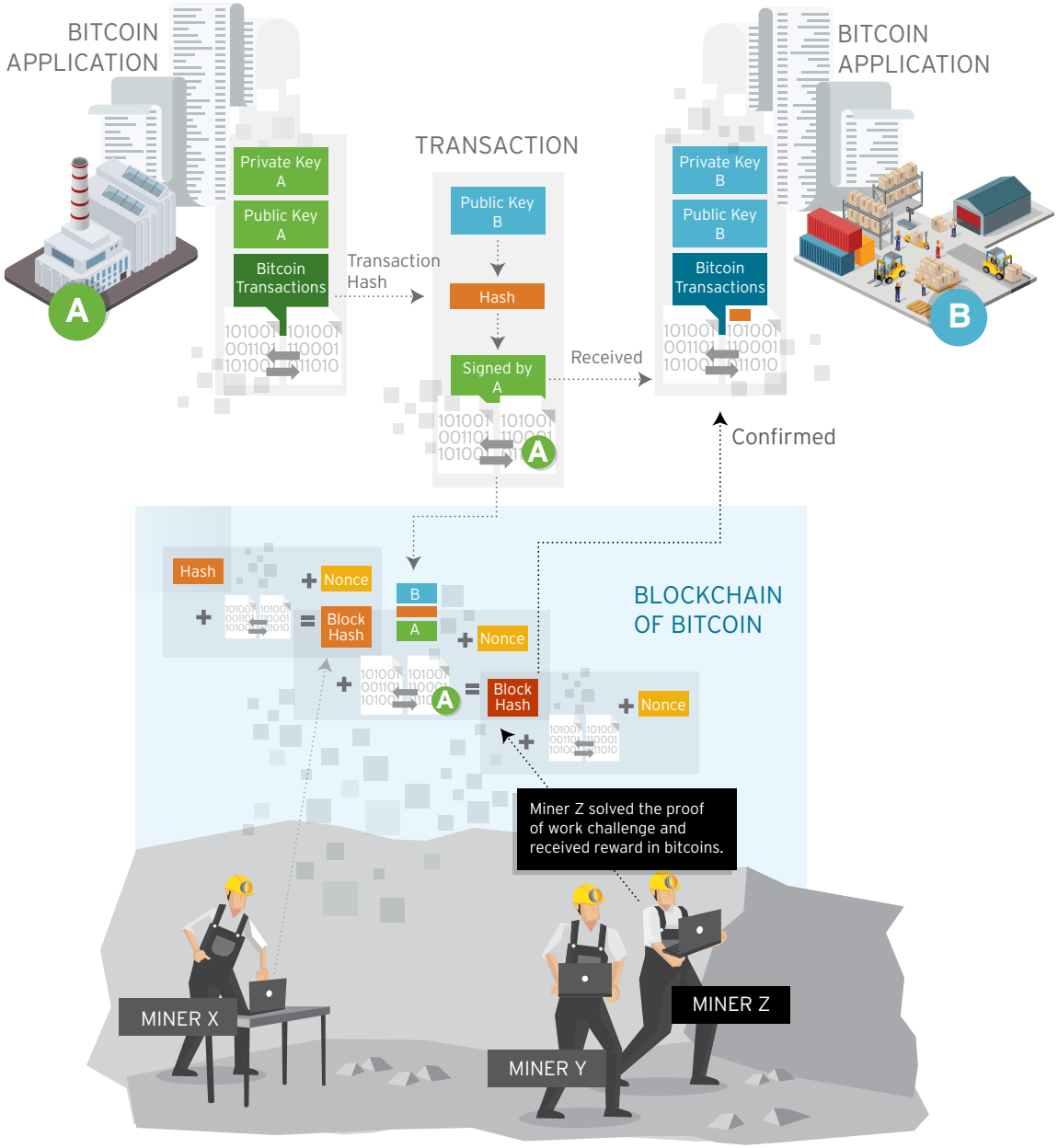

Figure 1

is just the beginning. In the long run it will enable more agile value chains, closer cooperation with business partners and faster integration with the Internet of Things (IoT), among other things.

Blockchain: A Deeper Dive

The initial objective of blockchain technology was to enable trusted financial transactions between any two parties without the need for a third party such as a bank. While it's best known in the financial services world, it can be used in any industry to enable faster, less expensive transactions and to support more agile supply chains that would be impossible otherwise.

When Satoshi Nakamoto introduced bitcoin in a white paper in 2008,[1] he did not use the term blockchain. But he laid the foundation for it by identifying the need to prevent "double spend" (two parties spending the same currency) without relying on a central trust authority such as a bank.

Solving this problem requires:

- Publicly "announcing" all transactions or changes to any of the currency, documents or transactions to all participants in a blockchain.
- Creating a system that allows all participants to agree on the transactions and their sequence.

It is the second requirement that gave birth to blockchain, a distributed database maintained by a series of servers. One server preserves a time stamp on all transactions on the blockchain. This server collects a set of transactions in blocks and publishes a hash (a unique set of numbers that, if changed, shows the data or transaction is invalid) for each block of transactions with a time stamp to verify their authenticity. As illustrated in Figure 1 (previous page), each owner of a transaction or document transfers the coin to the next owner by digitally signing a hash of the previous transaction and the public key of the next owner and adding these to the end of the block.

However, that leaves the problem of how to ensure the validity of each block without a central authority to track all transactions. Blockchain solves this by providing an incentivized proof-of-work task for each participant. This process, called "mining," involves attempting to find a numerical value, known as a "nonce," that when combined with all open transactions in a block can be "hashed" into a value that satisfies a certain "difficulty" but is also easily verifiable. Once the nonce is found by a miner, the miner publishes the block with a hash to the rest of the peer-to-peer network that makes up the blockchain. Other nodes accept the block, validate it and store it locally. The nodes then collect the next set of transactions and start another proof-of-work challenge. The node that solves the hashing challenge gets a reward in the form of bitcoins.

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The blockchain concept has been extended over the last six years for use not only with currency but other types of records as well as smart applications that can conduct transactions independently. Innovations such as the Ehtereum[2] platform for decentralized applications and the Hyperledger[3] project to create a cross-industry open standard for distributed ledgers are making distributed, trusted and secure blockchain technology increasingly relevant for the manufacturing industry.

Blockchain in Manufacturing

The need for compressed product lifecycles has led to increased conflicts between manufacturers and suppliers. One particularly sensitive issue is managing the development and engineering of a complex product in a way that protects both the manufacturer's and supplier's competitive edge and differentiation. Other issues over the lifetime of a product, such as fixing the responsibility in automotive recalls, are made more difficult and expensive by the lack of trust between partners on both the transactional and strategic levels (see Quick Take, page 6).

Imagine a not-too-distant scenario where smart products on the IoT must securely run embedded software, and instantly and securely share massive amounts of data among those applications. These capabilities will add more tiers to the supply chain and dramatically increase the number of players and latency for root-cause analysis and corrective actions at the design level.

If the past is any indicator, the emerging complexity of products and business models will make a lack of trust an ever greater drag on manufacturing supply chains. Manufacturing organizations must spend large amounts of time, money and effort on negotiation, communications and paperwork to overcome this absence of trust. This is

where the transformative power of blockchain lies, delivered by three critical capabilities:

- **Distributed integrity and reputation.** Blockchain gives a trading partner immediate and low-cost trust in the identity and reputation of the counterparty in any financial or trading relationship. This not only reduces the cost and time of transactions with known partners, but reduces the time and cost required to establish new business relationships. It also expands the universe of suppliers and customers for everything from raw materials to shipping and repair services, delivering quantum leaps in efficiency and agility.

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- **Built-in monetary incentives to assure the security of every transaction and asset in the blockchain.** This allows blockchain technology to be used not only for transactions, but as a registry and inventory system for recording, tracking and monitoring all assets across multiple value chain partners. This secure information can range from information about raw materials or work-in-progress to intellectual property such as product specifications, purchase orders, warranty recalls or any currency or contract.
- **The ability to tap rules-based intelligence to perform business functions.** Blockchains enable the creation of intelligent, embedded and trusted program code, letting participants build terms, conditions and other logic into contracts and other transactions. It allows business partners to automatically monitor prices, delivery times and other conditions, and automatically negotiate and complete transactions in real time. This reduces transaction costs, maximizes efficiency and allows manufacturers to use data in different ways. It also opens the door for machine-to-machine transactions across the IoT.

These capabilities enable the transformation of a traditional supply chain, where transaction documents and contracts must be maintained by each partner's purchasing, accounting or legal department. With blockchain technology, all transactional elements are stored on decentralized computing nodes by various partners.

Two important examples of how blockchain can change manufacturing and logistics are:

- **Smart contracts:**[4] A blockchain smart contract between a supplier and a buyer would consist not of a paper document in a drawer or a word processing document on a computer server. It would take the form of a computer program that runs on the blockchain and is executed by the entire blockchain network. Its program code – the terms and conditions of the contract – cannot be changed, and thus provides the trust that used to require elaborate control and audit processes. Not only can blockchain contracts contain the same level of detail as a physical contract, they can do something no conventional contract can: Perform tasks such as negotiating prices and monitoring inventory levels. This, again, replaces expensive, manual effort with automated, dynamic tracking of supply chains, inventory levels and prices to reduce costs and maximize profits.

  To understand the potential of such smart contracts, think back to the "digital marketplaces" of the late 1990s and early 2000s. They served the role of a centralized trust and transaction processing hub which connected multiple supply chain partners. Blockchain technology can transform the vision of an "any-to-any" marketplace into reality. Imagine, for example, a commodity seller publishing a smart contract on a blockchain platform such as Ethereum that includes exact terms and conditions for product specifications, delivery and payment. Any buyer on the blockchain can find and act on the contract, acquire the needed product or service and pay for it without the processing overhead of the early digital marketplaces.

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- **Smart equipment and products:** Consider, for example, a smart vending machine that registers itself on a blockchain platform and tracks its own inventory and cash position. The machine will not only issue a replenishment order when it needs restocking, but can find the needed products at the best price, and order and pay for them without manual effort or the involvement of its owner. We believe this ability of smart machines to decentralize

Order-to-Cash Process with Smart Contracts

By providing trusted, automated transactions without the need for third parties, blockchain enables efficiency and agility wherever products, information or payments change hands.

Figure 2

decision-making and execution will bring a new era of efficiency to the manufacturing value chain. This concept is also relevant for IoT and machine-to-machine (M2M) integration using distributed blockchain technology.

As illustrated in Figure 2, a supplier or manufacturer issues a smart contract (Smart Contract 1, highlighted in light blue) on a blockchain including product definition, quantity, price, availability date as well as shipping and payment terms. A buyer looking for the product can use the blockchain to find the smart contract, verify the reputation of the supplier/manufacturer for quality and timeliness and complete the transaction. This replaces the more difficult and expensive manual processing required to issue a purchase order to the supplier.

Next, a supplier will search for a smart contract (Smart Contract 2, highlighted in gold) from a carrier with details such as "origination, destination, capacity, shipping conditions, carrier fees and shipping time." The supplier will accept the smart contract from the carrier. When the product is delivered to the buyer, the delivery confirmation will close Smart Contract 2 and the supplier will pay the carrier the shipping fees in cryptocurrency.

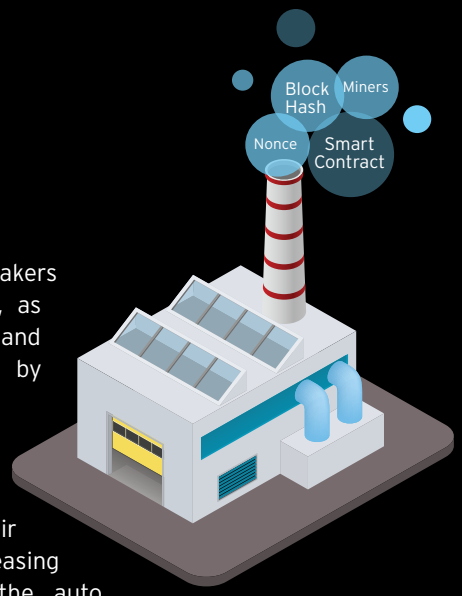
The delivery confirmation will also trigger a financial settlement in Smart Contract 1 between the supplier and buyer. In traditional supply chain processes, banks are used as the intermediary in the payments process. With smart contracts, the use of cryptocurrencies within blockchain will handle the settlement of funds.

The advantages of this approach include:

- **Low barriers to entry** for a supplier and a buyer to conduct the transaction.
- **The "reputation" of blockchain participants' performance on past smart contracts** will help the highest-performing companies to demand premiums.

Quick Take

Blockchain in Manufacturing: The Art of the Possible



The applications of blockchain technology across the manufacturing space are endless. What follows are a few examples.

- **Audit trails:** Blockchain audit trails prove that a shirt was made in a factory paying a fair wage that provides good working conditions. This allows the retailer to charge a premium, the customer to feel good about the purchase and the workers to live better. Using blockchain audits to prove that organic food (or cage-free eggs) is genuine, for example, can help justify premium pricing, while fostering more humane/sustainable agriculture.
- **Real-time negotiation:** Intelligent blockchain contracts continuously query all other nodes in a blockchain for the best pricing, delivery times, and other terms and conditions for specialized aircraft engine parts. An engine manufacturer, for instance, can ramp up to meet demand more easily while cutting costs, while a smaller manufacturer can more easily fill demand from major customers.
- **Supply chain visibility and traceability:** Blockchain production records, for example, can trace which automobile airbags were made with an explosive compound that can cause injuries or death. Automakers can reduce their liability, as well as their customer and vehicle tracking costs, by more quickly identifying the vehicles in which the airbags were used. Customers know more quickly whether their vehicle is affected, increasing their satisfaction with the auto brand and reducing their risk of injury or death.
- **Tapping data from IoT:** Easily tracked and authenticated blockchain data from IoT gives manufacturers more and better data about how their products perform over time, enabling them to improve quality. This also helps them move beyond production to more lucrative sales and services such as proactive replacement of failing parts.
- **IP management in product development:** Blockchain technology makes it easier and less expensive to securely share intellectual property such as designs, bills of material and production schedules among suppliers, manufacturers and shippers.

- **Smart equipment can replace human contracting parties for certain transactions,** as in our example of the vending machine.
- **Devices on the IoT can communicate with smart contracts to keep track of the status and state of smart contracts for settlements.** Smart shipping containers could, for example, automatically sell their surplus capacity.
- **Faster settlements** using cryptocurrencies.

Getting Ready for Blockchain

Manufacturing value chains are complex, multi-tiered combinations of various types of organizations providing design, sourcing, manufacturing, delivery and service across multiple geographies. Producing even a single component of a single product may involve a myriad of transactions, ranging from requests for quotes to the transmission of purchase orders and engineering change notices. Each transaction type may require different financial and regulatory intermediaries, as well as its own contract and trust relationship among the parties. The immediate and low-cost assurance of trust provided by blockchain technology can unleash disruptive innovation by allowing any supplier and any manufacturer to instantly find one another and begin a trading relationship.

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So far, disruptive innovation in blockchain is being driven primarily by technology start-ups with a high tolerance for risk. Nonetheless, the overall trajectory of blockchain technology is extremely high (see Figure 3, next page). As a result, we

Pace of Blockchain Adoption

We expect the pace of blockchain's disruptive innovation to accelerate in the next 18 to 24 months.

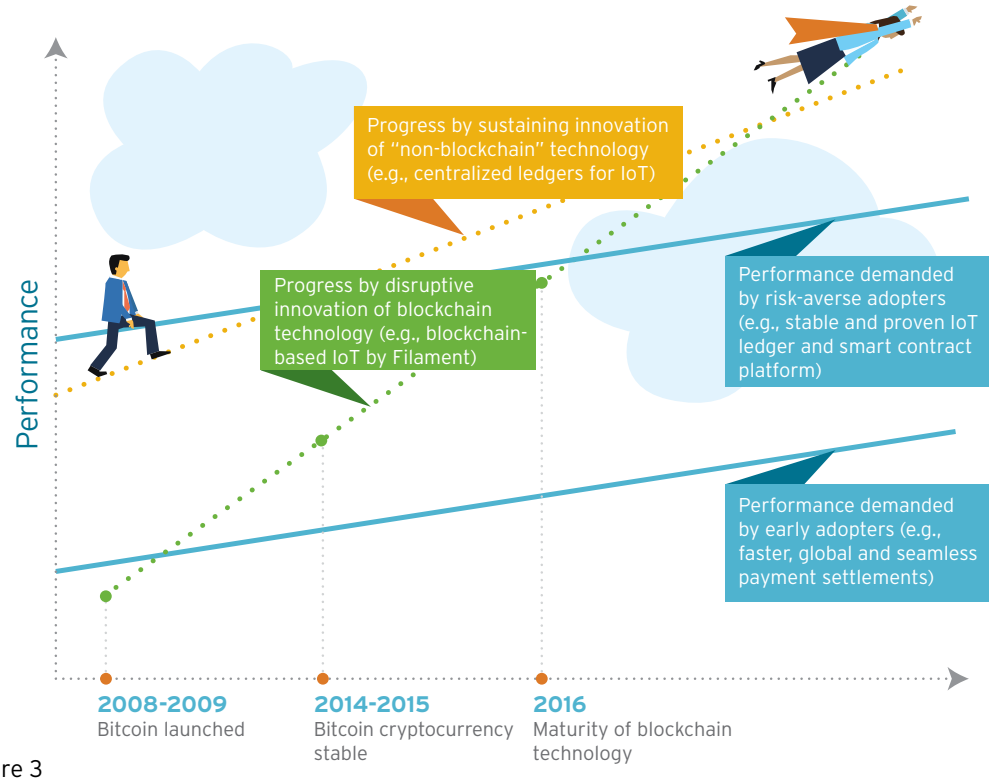


Figure 3

expect the next 12 to 18 months to be extremely important for companies looking to develop their blockchain innovation strategies.

As is typical with disruptive technologies, we recommend first executing proofs of concept to understand its potential and limitations, rather than measuring early deployments on their return on investment.

To help companies understand the relevance of blockchain smart contracts to them, and target their proofs of concept most effectively, we use two tools.

The first is the decision chart shown in Figure 4, next page, which helps identify areas where blockchain technology can deliver value.

One such area is in transactions where both parties lack trust in the definition and verification of a successful transaction. For example, Blockcharge[5] uses blockchain technology to provide the authentication of users and billing for a peer-to-peer network of charging stations for electric vehicles without the need for a middleman such as a bank.

A second useful tool to identify "low hanging fruit" blockchain opportunities is the functional complexity-automation capability framework shown in Figure 5 (next page), developed by authors and scholars Don and Alex Tapscott.[6]

Applying these two tools to the use of smart contracts in two manufacturing value chain transactions – the selling and purchasing of goods and services – produces a sound decision framework, as seen in Figure 6, page 9.

Challenges and Risks

Blockchain carries all the risks of any emerging technology. These range from the maturity of the technology itself to the standards surrounding it to the challenges of integrating it with existing platforms and business processes. The instant provision of trust among trading partners, and the ability of smart contracts to negotiate and finalize transactions, may require major changes in workflows and business processes.

Due to its disruptive nature, however, blockchain also carries two unusual risks potential adopters should monitor carefully.

Blockchain Smart Contract Relevancy Decision Chart for Manufacturing Value Chain Transactions

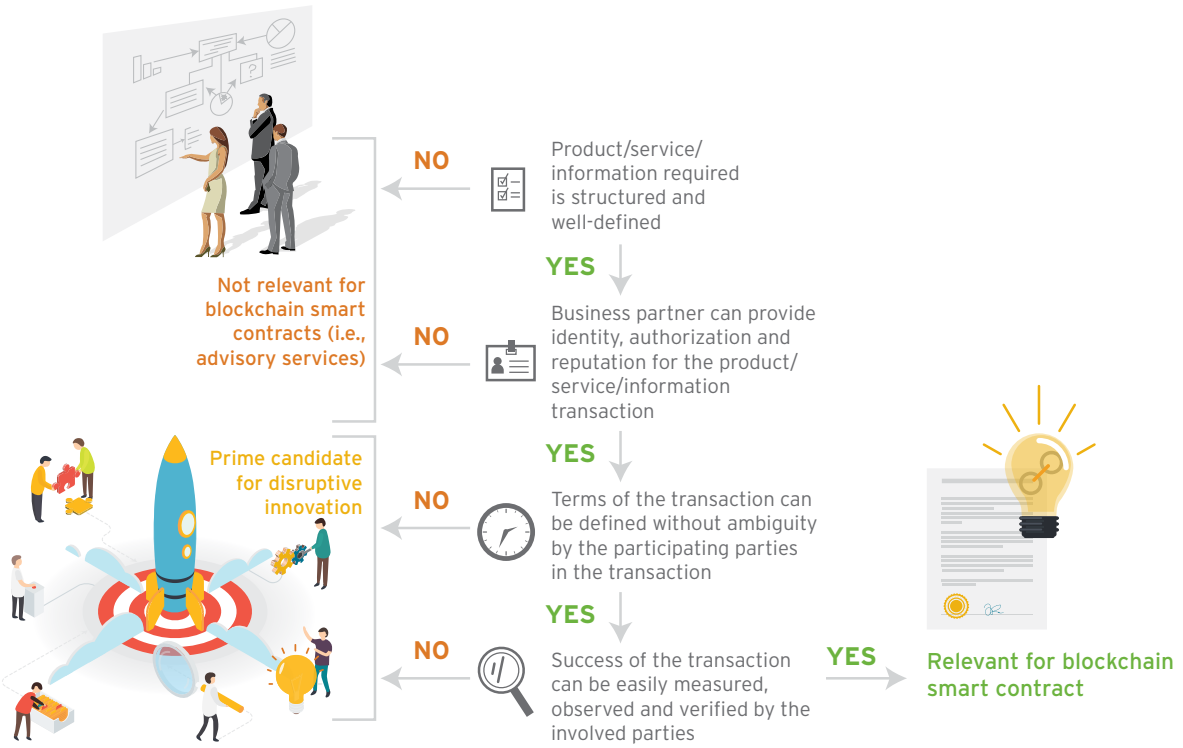
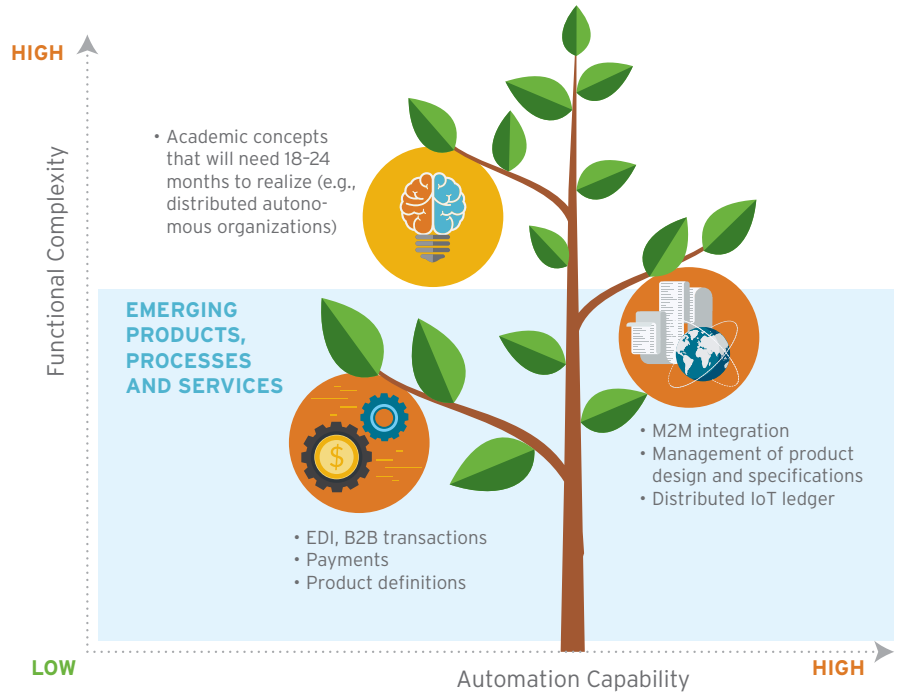


Figure 4

The Low-Hanging Fruit: Where to start with Blockchain Innovation



Source: Adapted from Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World, *by Don Tapscott and Alex Tapscott, Penguin Random House, June 2016.*

Figure 5

Where Blockchain Works Best

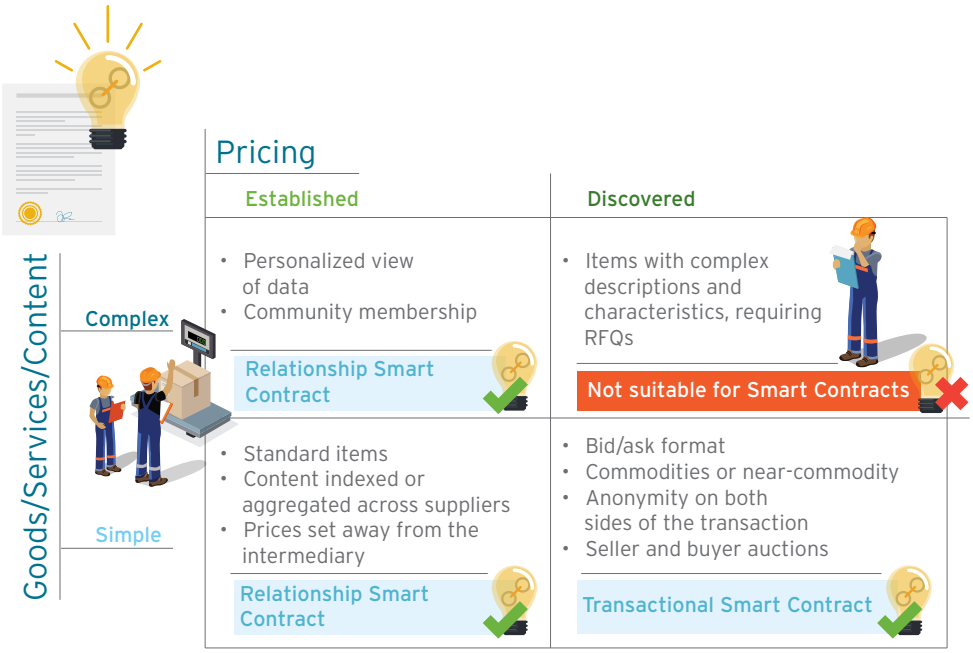


Figure 6

- **Government acceptance of or interference in blockchain peer-to-peer networks.** Many governments have not authorized the use of blockchain cryptocurrencies due to their lack of control over the monetary effects of cryptocurrencies and concerns over the criminal exploitation of the decentralized peer-to-peer network. When choosing blockchain opportunities, organizations should carefully consider where such lack of government acceptance would reduce or eliminate the value of blockchain in its value chains.
- **Resistance from established players such as banks, exchange networks and other trust intermediaries could delay blockchain adoption.** Manufacturers may want to trial initial blockchain rollouts with smaller, newer "true digital" trading partners than larger partners unwilling to endanger their relationships with existing intermediaries.

Looking Forward

Blockchain isn't just for banking and currency. Deployed correctly, its central benefit of rapid, easily established trust among trading partners can enable disruptive innovation in areas ranging from audit trails, real-time negotiation, supply chain visibility and tapping data from the IoT to managing intellectual property in product development. This trust can more quickly match suppliers with the manufacturers that need their products, and slash the costs and delays associated with traditional accounting and vendor management.

But blockchain technology and standards are still emerging. Resistance from governments and existing intermediaries could slow its progress. As with any new technology, integrating blockchain with existing technologies and new platforms such as IoT, and adapting skills and business processes to it, will require investment.

Enterprises should proceed cautiously, with proofs of concept executed with partners, as they identify the "sweet spots" for this powerful new capability. We recommend that manufacturing companies do the following:

- Implement block chain technology evaluation and selective proofs of concept.
- Begin developing and testing innovative block chain business models and products.
- Leverage experienced partners to build a blockchain technology (hardware and software) lab to best understand the ever-changing potential and challenges.

Footnotes

[1] https://bitcoin.org/bitcoin.pdf

[2] www.ethereum.org/

[3] www.hyperledger.org/

[4] Nick Szabo, http://szabo.best.vwh.net/smart.contracts.html.

[5] www.youtube.com/watch?v=0A0LqJ9oYNg

[6] Don Tapscott & Alex Tapscott, *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World*, Penguin Random House, June 2016, http://blockchain-revolution.com/the-book/.

About the Authors

Prasad Satyavolu is Global Head of Innovation within Cognizant's Manufacturing & Logistics business unit, where he focuses on the connected world (connected products, processes and infrastructure), including connected car and telematics services, IoT solutions for urban mobility and smart cities. He also focuses on customer fulfillment (integrated supply chain management that spans visibility planning and manufacturing execution) and general manufacturing industry challenges. Over the last 25-plus years, Prasad has held leadership roles in manufacturing and logistics and incubated a start-up in IT services and consulting that served the manufacturing industry. He holds an advanced degree in mechanical engineering from Dayalbagh Educational Institute, Dayalbagh, Agra, India, and completed a General Management Program (MEP) at Indian Institute of Management, Ahmedabad, India. He can be reached at Prasad.Satyavolu@cognizant.com.

Abhijeet Sangamnerkar is a Senior Business Transformation Leader and AVP within Cognizant's Manufacturing & Logistics business unit. He has over 20 years of consulting experience in the automotive, pharmaceuticals, chemicals and A&D industries. Abhijeet provides advisory services specializing in digital transformation strategy, business cases and roadmaps, and has managed several global transformation programs in the manufacturing industries. He holds an MBA from the Kellogg School of Management, Northwestern University, and a B.E. in electronics engineering from Gov't College of Engineering, Pune University, India. Abhijeet can be reached at Abhijeet.Sangamnerkar@cognizant.com.

About Cognizant

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World Headquarters
500 Frank W. Burr Blvd.
Teaneck, NJ 07666 USA
Phone: +1 201 801 0233
Fax: +1 201 801 0243
Toll Free: +1 888 937 3277
Email: inquiry@cognizant.com

European Headquarters
1 Kingdom Street
Paddington Central
London W2 6BD
Phone: +44 (0) 20 7297 7600
Fax: +44 (0) 20 7121 0102
Email: infouk@cognizant.com

India Operations Headquarters
#5/535, Old Mahabalipuram Road
Okkiyam Pettai, Thoraipakkam
Chennai, 600 096 India
Phone: +91 (0) 44 4209 6000
Fax: +91 (0) 44 4209 6060
Email: inquiryindia@cognizant.com