

Blockchain in the Factory of the Future

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Blockchain in the Factory of the Future

Like the rest of the world, the factory is rapidly becoming more interconnected. In **the factory of the future**, data sharing occurs across a complex network of machines, parts, products, and value chain participants, including machinery providers and logistics companies. As a result, today, more than ever, manufacturers face the challenge of securely sharing data within and outside the factory walls.

Traditional databases are not always well suited to the task. But in seeking a solution for specific applications, manufacturers can explore an emerging technology: blockchain.

A blockchain is a digital ledger that provides a single, tamperproof version of truth. The technology offers unique advantages in situations where trust is lacking between parties that need to securely capture, store, and share critical data—for instance, data related to intellectual property (IP). Manufacturers can also apply blockchain to develop innovative business models and expand the boundaries of production beyond the traditional factory.

For many factory applications, however, blockchain is not the best option. Recently developed central ledger databases that offer some of the features of blockchain are easier to implement and can process more transactions. And other types of databases are appropriate when parties need to store and process large volumes of data in real time.

To pinpoint situations where blockchain is the right technology to use to support operations, a manufacturer must conduct a structured assessment, starting with identifying the company's current business problems and future needs. Next, it can explore how to use the technology to relieve the factory's pain points and address its needs. Equipped with a strong understanding of the opportunities and challenges it faces, the manufacturer can then select the best options from among the available technology solutions.

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Is Blockchain Ready for the Factory?

To ensure trust among value chain participants, manufacturers have traditionally relied on strong supplier relationships, independent quality audits, “six sigma” practices, and extensive documentation. Unfortunately, these practices typically entail high costs, known as a *trust tax*. By ensuring trust more efficiently—in addition to conferring other benefits—blockchain reduces the need for these expensive approaches. (See the sidebar, “[Breaking Down Blockchain's Benefits](#).”)

Here, in basic terms, is how blockchain works: When a participant in the network submits an update to a blockchain ledger, the database uses an automated process to ask other participants to approve the update. Approved updates are time-stamped, cryptographically signed, and added to the block. The new block becomes part of the blockchain, an immutable record of all transactions and agreements of interest to the participants.

The originators of blockchain developed it to provide a technological foundation for digital currency. Early generations of blockchain did not support industrial applications effectively, owing to limitations in network scalability, interoperability, and processing speed. The versions now under development, however, use new consensus protocols that improve the efficiency of the verification process by increasing the number of transactions per second and reducing computing costs.

The improvements under development will enhance interaction between [blockchain technology and the Internet of Things \(IoT\)](#)—a prerequisite for enabling blockchains to connect networked devices in the factory of



Breaking Down Blockchain's Benefits

Blockchain's technical features provide four key advantages over traditional databases:

- **Trust.** Because the network validates every transaction, the blockchain holds a single version of the truth that all participants can trust.
- **Security.** Cryptographic signatures, automated verification, and decentralized storage make it virtually impossible for external parties to modify the ledger or delete data, thus securing it indefinitely. Although users can append data to a blockchain, they cannot otherwise alter the ledger.
- **Automation.** A blockchain ledger lets network participants set up a wide range of self-executing agreements, contracts, and escrows (known as smart contracts), thereby automating repetitive processes such as billing and shipping. A blockchain can execute any contract triggered by measurable conditions—for example, equipment performance or on-time delivery of goods.
- **Resilience.** Because the database is distributed across multiple locations in the network, the blockchain can continue to operate even if part of the network fails. And if a party leaves a network, none of the data it has posted on the blockchain will be lost.

the future. The interaction demands a common technical standard for communication and data transmission. Such a standard will promote levels of interoperability, transparency, and security that are superior to those of existing systems and platforms. But because no common standard exists yet, many blockchain applications have not proceeded beyond the proof-of-concept phase.

Although blockchain is becoming simpler to deploy in the factory, it is not a panacea for challenges in industrial operations.

Efforts are underway to unleash blockchain's potential in manufacturing. For example, the Trusted IoT Alliance, a collaboration among leading technology companies (including Bosch and Cisco Systems) and numerous startups, is developing an open-source standard for integrating blockchain and the IoT. The standard focuses on a smart-contract interface that allows data to move seamlessly within and between blockchain-enabled systems.

Although the Trusted IoT Alliance's earliest proof-of-concept applications focus on the supply chain, the developers envision creating other applications that will support immutable documentation and trusted hardware identification. Once established, a standard could be integrated into new factory hardware and software to expand blockchain applications.

The recent launch of blockchain as a service (BaaS) is also helping to smooth the path toward implementation of blockchain in the factory. Traditional blockchains are self-managed, meaning that a company must customize the database's capabilities (for example, how it manages cryptographic keys) and organize the hosting of the nodes either locally or in the cloud. BaaS offers the same features as a self-managed blockchain (such as security for critical data) and adds tools that facilitate management and deployment at scale. For many manufacturers, especially those with resource-constrained technology teams, using BaaS will be easier than implementing a self-managed blockchain.

Although blockchain is becoming simpler to deploy in the factory, it is not a panacea for challenges in industrial operations. A case in point is real-time data. For applications that require nearly immediate data exchange, such as the on-line steering of production equipment, the latency time entailed in using blockchain is excessive. In a similar vein, blockchain technology is not suitable for running advanced analytics—a capability of increasing importance in factory operations.

In assessing appropriate opportunities to use blockchain, manufacturers should consider whether other databases are better options. (See Exhibit 1.) Recently developed central ledger databases offer some of the benefits of blockchain (including trust and immutability), although they are applicable to fewer use cases. On the positive side, they are easier to set up and can handle more transactions. Because a trusted central party manages these ledger databases, executing transactions does not require multiparty consensus. Each type of database has its own tradeoffs in performance and functionality; there is no one-size-fits-all solution.

How Blockchain Can Create Value in the Factory of the Future

We have selected five use cases for blockchain in the factory of the future to illustrate the many available opportunities. Three of these use cases help enable other factory-of-the-future applications, while the other two make new business models possible. (See Exhibit 2.)





ENHANCING TRACK AND TRACE

Companies can use blockchain to exchange data easily, accurately, and securely within complex [supply chains](#). Blockchain can provide an immutable, permanent digital record of materials, parts, and products, thereby promoting end-to-end visibility and providing a single source of truth to all participants. These benefits are valuable if the supply chain includes multiple participants with independent IT systems, or if there is a lack of trust among participants or a frequent need to onboard new participants.

Five Use Cases Illustrate the Opportunities



Exhibit 1 | Comparing Decentralized and Centralized Databases

| | Decentralized | Centralized | | |
|---------------------------|--|--|---|---|
| | Blockchain database (self-managed or BaaS) | Central ledger database | NoSQL/ data lake | Relational database |
| Example |  Hyperledger Fabric, Amazon Managed Blockchain |  Amazon Quantum Ledger Database |  MongoDB |  Microsoft SQL Server |
| Immutable | Yes | Yes | Not by default | Not by default |
| Trust | Guaranteed | Guaranteed, but relies on central party | Not guaranteed | Not guaranteed |
| Processing speed | Medium | High | Very high | Very high |
| Ease of implementation | Moderate to difficult | Moderate | Moderate | Easy |
| Best use | Storing and sharing critical data input by multiple parties | Storing and sharing critical data input by multiple parties, but fewer use cases than blockchain | Storing very high volumes of IoT or other data for advanced analytics and AI applications | Flexible storage of structured data, typically owned and used by a single entity |

Source: BCG analysis.

Note: AI = artificial intelligence; BaaS = blockchain as a service; IoT = Internet of Things; NoSQL = not only SQL; SQL = structured query language

PROTECTING AND MONETIZING CRITICAL INTELLECTUAL PROPERTY

Companies across manufacturing industries face an imperative to protect IP. Along with cost, IP protection is a critical consideration in decisions about whether to make parts in-house or to buy them from a supplier).

One possibility is for a company to use blockchain technology to help prove that it owns IP in the event of a patent dispute. For instance, Bernstein Technologies has developed a web service that allows users to register IP in a blockchain. The service creates a certificate that proves the existence, integrity, and ownership of the IP.

Blockchain is also one of several solutions available to help a company protect and maintain control of IP when

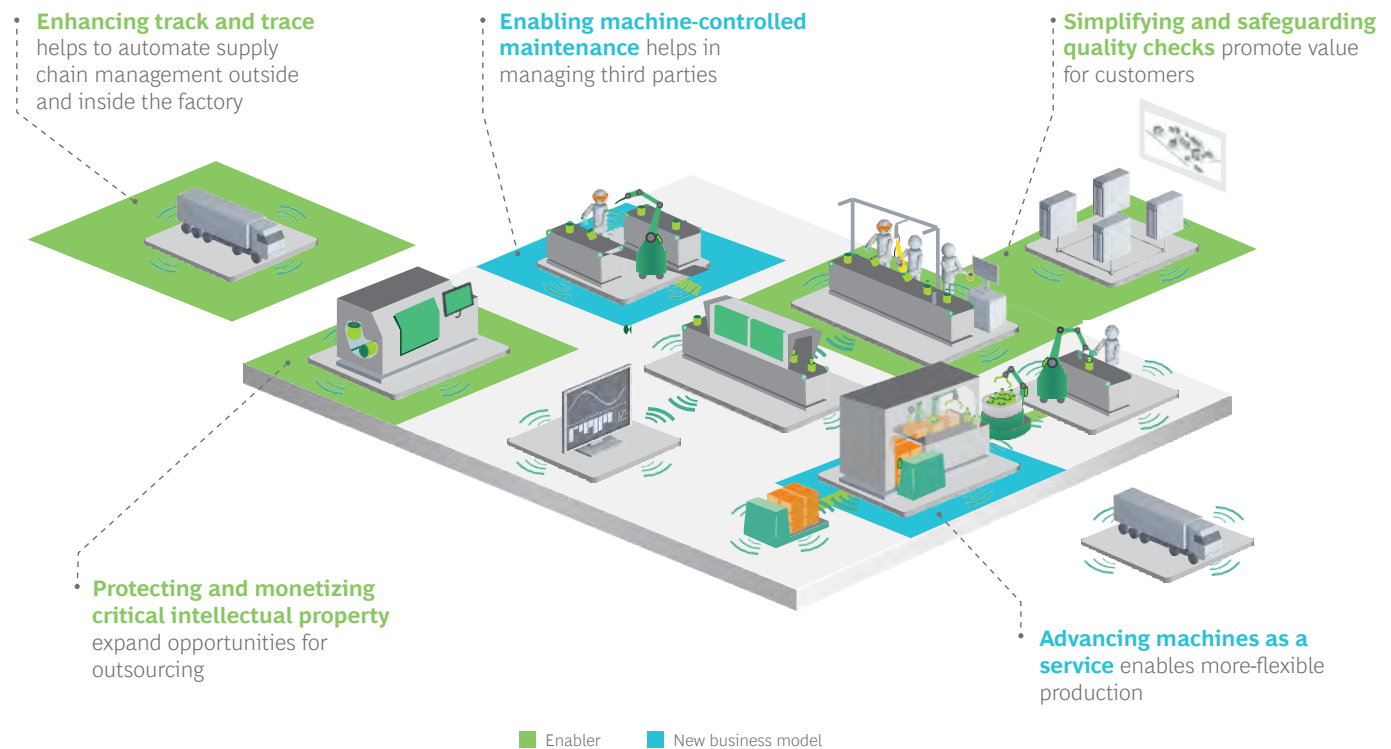
monetizing digital assets. For instance, machines connected to a blockchain can produce parts by using digital design files included in the database. The company that owns the IP uses a licensing model to make the proprietary information available through the blockchain to the company that produces the part.

Blockchain can provide an immutable, permanent digital record of materials, parts, and products.

SIMPLIFYING AND SAFEGUARDING QUALITY CHECKS

By using blockchain to support quality control, a company can enhance value for customers, another primary objective of the factory of the future. Today, in the absence of blockchain, offering full transparency and complete documentation to customers with regard to the quality of

Exhibit 2 | Blockchain Applications Enable and Enhance the Factory of the Future



Source: BCG analysis.

processes and products requires costly support from central parties that operate IT platforms.

In addition to helping customers track and trace inbound parts along a supply chain, blockchain creates immutable documentation of quality checks and production process data. The database uniquely tags each product and automatically inscribes every transaction, modification, or quality check on the blockchain. To enable this application, the production setup must include automated quality checks that generate and write measurements directly to the blockchain. This use case supports multiparty access to data and can eliminate the need for inbound quality control to verify checks that the supplier performs. It may also reduce the need for audits by original-equipment manufacturers or central authorities to verify quality controls. Parties will be able to use the technology's certificate-management capabilities to gain full transparency into all relevant documents, thereby ensuring authenticity.

Two examples from aircraft manufacturing illustrate the opportunities:

- **Tracking the Provenance of Components.** Aircraft manufacturers are testing the use of blockchain

applications to track the provenance of aircraft components, which existing technologies struggle to do because aircraft production requires a multitude of parts produced by different suppliers. Manufacturers can use blockchain to prove the origin of parts and to verify that the parts meet the appropriate specifications.

- **Configuration Management.** Companies can use blockchain to create an immutable ledger of all aircraft components and embedded software—whether original, substituted, or added—and to manage the respective certificates of functionality or performance. This approach ensures transparency into aircraft configurations and permits automated recognition of any mismatch between certificates and components. Several initiatives are separately underway to develop such an application. For example, Honeywell has launched an online marketplace for aviation parts that uses blockchain to ensure accurate quality documentation for every part. Most large aircraft manufacturers have announced plans to test similar blockchain-enabled trading platforms.

Manufacturers can use blockchain to prove the origin of parts and to verify that they meet the appropriate specifications.

Aircraft manufacturers are testing the use of blockchain to track the provenance of components.



One example of how manufacturers can use blockchain to control their products after production involves cost and performance management. Blockchain can provide a flexible, comprehensive system—not owned by a single manufacturer, supplier, or operator—for logging and tracking all relevant information about parts. This includes data about raw materials, usage (if logged by embedded IoT capabilities), maintenance cycles, and performance testing. Participants gain access to a complete, auditable log of a particular part. Users can gather insights into the history of component configurations and product performance throughout a part's lifetime and feed them into the R&D process to optimize component complexity, cost, and performance. In the aircraft industry, for example, Boeing is currently in an early stage of developing a business intelligence platform for cost and performance optimization.

Blockchain can enable the automated execution of, and payment for, scheduled maintenance.

The main challenge in using blockchain for quality checks involves ensuring trust by linking a physical object to its digital replica (known as a *digital twin*). This connection must either prevent or reveal any human interference that alters information. To help create such a connection and maintain an accurate digital twin, more and more devices will contain sensors that can communicate with blockchains.

ADVANCING MACHINES AS A SERVICE

Blockchain expands the possibilities for using an innovative pay-per-use model for machinery, known as *machines as a service* (MaaS). In this model, rather than selling production equipment, a machinery provider charges for the equipment's use on the basis of the output it generates. For example, instead of selling a compressor, the machinery provider sells compressed air by volume. By relying on MaaS rather than owned machines, manufacturers can avoid large upfront investments and can easily upgrade equipment to gain access to the latest technology. Applied effectively, the MaaS model enables manufacturers to increase their production flexibility.

Today, MaaS is limited to easy-to-measure applications. But blockchain can support more complex MaaS applications by facilitating IP protection, documentation management, and performance tracking. By feeding an accurate record of use—enabled by blockchain's authentication features—into smart contracts, a machine can automate payment for services. For example, by inputting its operational parameters (such as overall equipment effectiveness and consumables usage) into the blockchain, a machine can automatically trigger a payment by the manufacturer that is using the equipment.

Blockchain can also enable users to activate built-in features on demand. Companies are currently testing the use of blockchain for automated MaaS payment systems.

ENABLING MACHINE-CONTROLLED MAINTENANCE

Blockchain can support new maintenance approaches (such as automated service agreements) and shorter maintenance times. These innovations are necessary to manage the greater complexity and technological sophistication of advanced production machinery.

To facilitate outsourced maintenance, users append service agreements and installation documentation related to each device to the blockchain record, creating a digital twin of the device. Blockchain technology can then enable the automated execution of and payment for scheduled maintenance. A machine that requires maintenance can trigger a service request and generate a smart contract for the work or for a replacement part. Upon fulfillment of the order, payment processing occurs automatically. Similarly, immutable documentation of the maintenance history is appended to the blockchain record. Such applications, which are still in the early development phase, improve the reliability of equipment, facilitate the monitoring of equipment health and attrition, and create auditable health assessments of the machinery. In addition, in the context of maintenance performed by in-house teams, the blockchain record can serve as proof to equipment providers that the team has executed maintenance in accordance with requirements set out in the warranty and guarantee agreements.

Immutable documentation of maintenance history also facilitates the sale of used equipment. In the future, shorter product life cycles and rapid design changes will motivate manufacturers to upgrade their machinery more frequently. When selling used equipment, a manufacturer can direct prospective buyers to the blockchain record for evidence that it has properly maintained the equipment.

Blockchain Vision: A Shared Factory for Additive Manufacturing

Envisioning these use cases in a shared factory for additive manufacturing (AM) illustrates the potential of blockchain. Until recently, companies primarily used AM either for prototyping or for manufacturing low-volume parts. Today, however, they are more widely adopting AM in *industrial manufacturing processes*.

As manufacturers ramp up their use of printed parts, outsourcing to a shared AM factory offers an attractive way to optimize the cost, speed, and feasibility of production. For example, manufacturers can print and obtain spare parts

faster and can produce unique or low-volume parts more economically. But before they can use outsourced AM, manufacturers must overcome several obstacles. These include protecting IP, creating direct digital connections with the AM factory, and ensuring adherence to quality and process standards. Today, manufacturers generally rely on an intermediary (referred to as a *3D printing platform*) to overcome these obstacles and identify the best print shop or service bureau for making a part. An automated blockchain bidding platform that uses smart contracts eliminates the need for support from 3D printing platforms.

An automated blockchain bidding platform that uses smart contracts eliminates the need for support from 3D printing platforms.

Within shared AM factories, the five blockchain use cases that we discussed earlier are currently in the proof-of-concept phase. (See Exhibit 3 for highlights of the three enablement use cases.) They offer the following advantages:

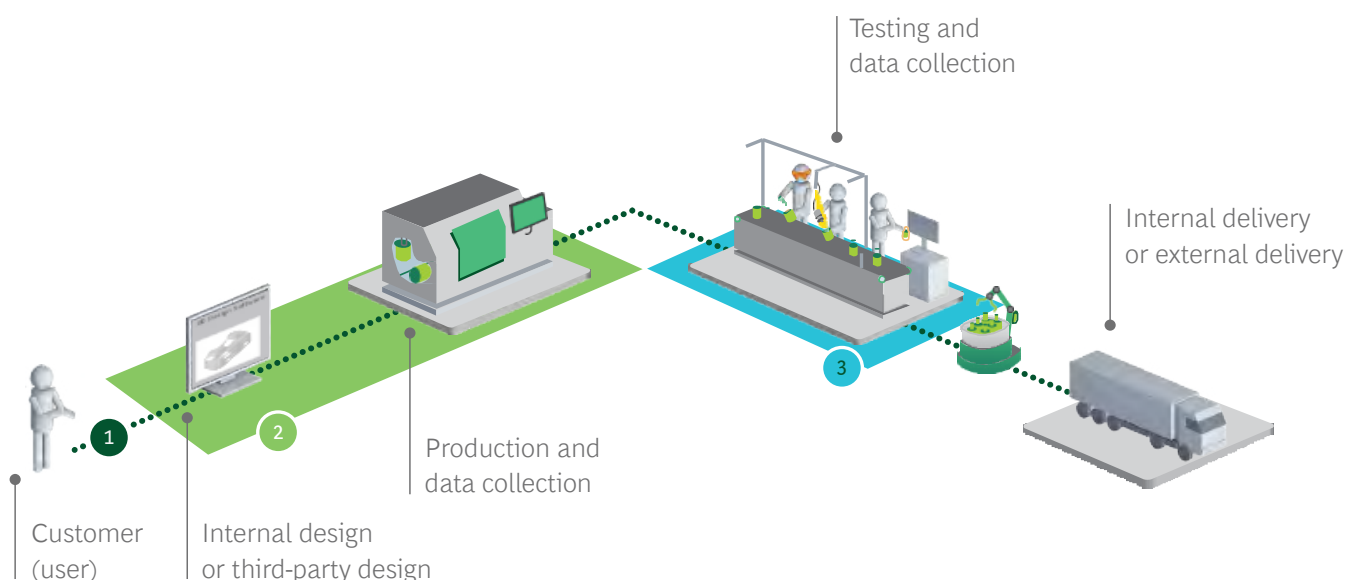
- **Comprehensive and Trusted Tracking of All Production Steps.** On a single IT platform, the customer can monitor progress as well as any deviation from the scheduled plan. This interoperable, blockchain-based platform is independent of the selected print shop or service bureau, thus reducing cost and the need for multiple databases.
- **Protecting IP by Using an Encrypted, Immutable File.** This is particularly relevant for designs involving critical IP or being used in regions where IP security is

especially at risk. To facilitate the outsourcing of AM processes, a consortium project called Genesis of Things is developing a platform that will allow parties to share digital design files in a safely encrypted blockchain format that is accessible only for the defined number of printouts. Companies contributing to the project include Cognizant, Commerzbank, and Innogy.

- **Offering Transparency into Quality.** Blockchain-enabled 3D printers control and document the raw material and process parameters used, and the output of the printing process. These functions validate quality for customers and end users.
- **Executing Machine-Controlled Maintenance.** Sensors attached to AM machines can trigger maintenance requests, and related smart contracts on the blockchain control fulfillment of and payment for the work.
- **Enabling MaaS Offerings.** Blockchain allows AM machine vendors to reliably prove that a machine or product meets contract goals. It also supports the execution and auditing of the financial transaction, promoting trust among all parties.

In order to capture these benefits in AM factories, manufacturers must advance use cases beyond the proof-of-concept phase and improve technology so that factories can conduct additive production economically. Moreover, a critical mass of end users must recognize the need to outsource AM, either because they lack the necessary internal resources and capabilities or because they require the specialized services that an AM factory offers.

Exhibit 3 | How a Shared Additive-Manufacturing Factory Could Benefit from Blockchain



Use case:

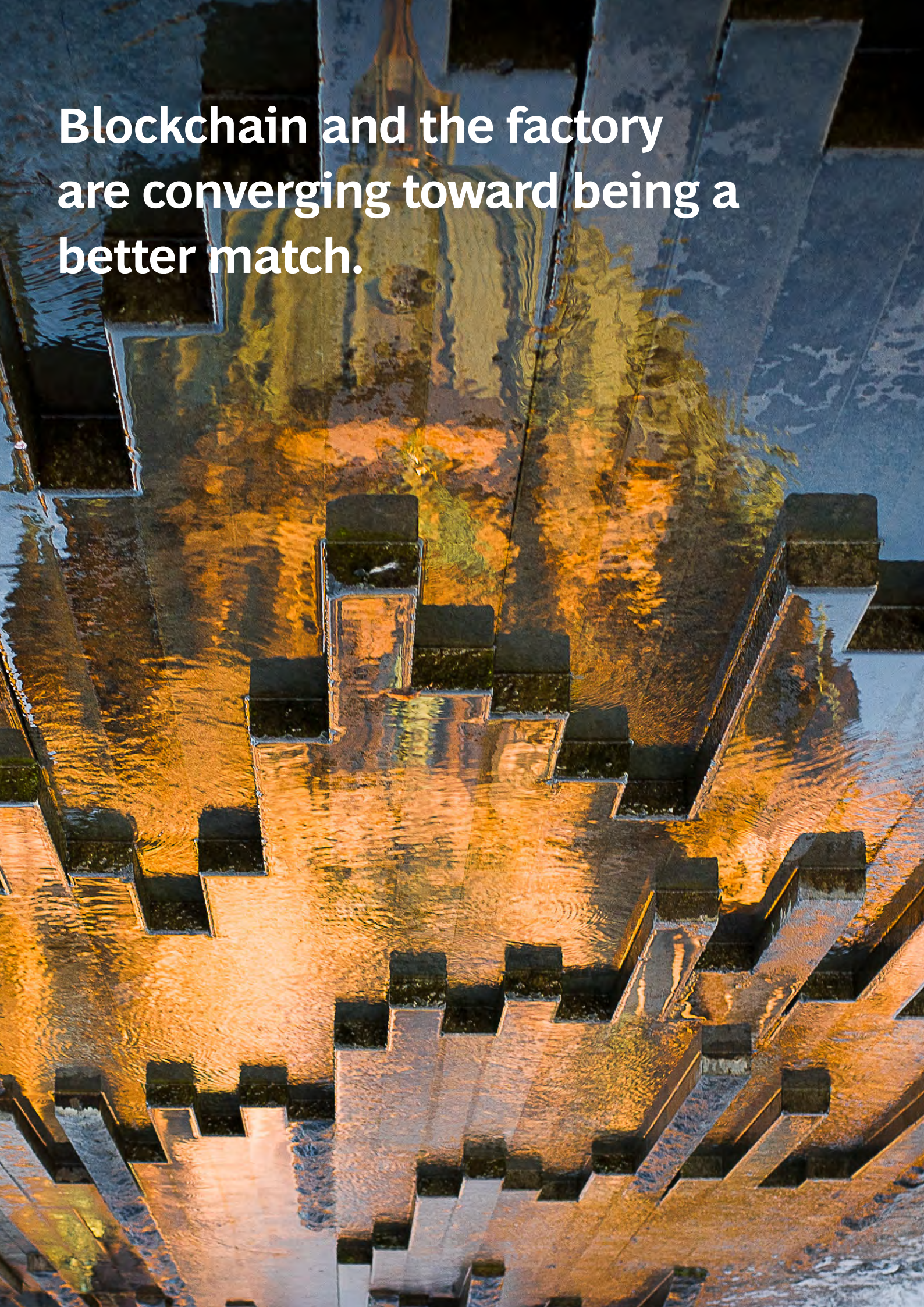
Enhancing track and trace

Protecting and monetizing critical intellectual property

Simplifying and safeguarding quality checks

Source: BCG analysis.

**Blockchain and the factory
are converging toward being a
better match.**



Assessing the Applicability of Blockchain Use Cases

Prior to selecting which blockchain use cases to pursue, manufacturers should conduct a multistep assessment. (See Exhibit 4.) The assessment of applicability should touch on six factors:

- **Desirability.** The manufacturer should first consider whether a use case can address one or more existing pain points and business needs and thereby generate benefits. The manufacturer should also consider obstacles to capturing the desired benefits. For example, multiple parties must be willing to adopt blockchain as the new technology for exchanging information and making payments, and they must transition away from using their traditional databases as the source of truth. To fully account for potential benefits, the manufacturer should also consider the network effects (such as an acceleration of benefits along the supply chain) once a critical mass of stakeholders has adopted a blockchain use case.
- **Feasibility.** For each desirable use case, the manufacturer should assess the effort required for implementation. This includes reviewing the operational feasibility (such as the ability to integrate the use case with other systems), and the time frame required for implementation.
- **Viability.** The manufacturer must evaluate the business case for investing in feasible use cases. Assessing economic viability includes considering both the financial impact and the risks entailed.
- **Regulatory Considerations.** To assess whether to pursue use cases that involve smart contracts, the manufacturer must understand the regulatory landscape in each country where its supply chain partners are located. Some countries and jurisdictions do not yet recognize smart

contracts as legally binding. In addition, regulations that govern the storage of sensitive data may present obstacles to using blockchain.

- **Strategic Alignment.** Each blockchain-enabled approach or business model must be aligned with the overall company strategy. If an approach or business model undermines or conflicts with other initiatives or policies, the manufacturer will have to mitigate the negative effects of the mismatch in order to pursue the blockchain option.
- **Technical Validation.** The manufacturer should validate that blockchain is indeed the right technology to adopt in order to achieve the objectives of the use case, compared with using a central ledger database or some other type of database. This involves conducting technical due diligence to evaluate issues such as whether the technology is mature enough and whether in-house capabilities are available—and if they are not, the due diligence effort must consider how to enhance the manufacturer's technology and capabilities.

Blockchain and the factory are converging toward being a better match. The latest blockchain protocols seek to increase processing speed and improve data privacy and governance. And as the technology quickly matures, factory operations increasingly require data sharing and collaboration among complex networks of companies and machines. By forging trust and connections within these complex networks, blockchain can help manufacturers clear some hurdles that have impeded the full-scale deployment of other next-generation technologies and innovative business models. Even so, blockchain is not a panacea, and other databases remain a better choice for specific applications. Armed with a detailed assessment of pain points and a prioritized set of use cases, a manufacturer will be well positioned to match the right technology solution to its most important business needs.

Exhibit 4 | A Framework for Evaluating Blockchain Use Cases



Source: BCG analysis.

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