**Blockchain - Applications in multiple domains**

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**1.1 Definition and Overview of Blockchain**

Blockchain is a new kind of database that allows for unrestricted data sharing inside an organization's infrastructure. A blockchain database stores data inside a series of blocks that connect together. Due to the need of network clearance for any alterations or removal of the chain, the data remains consistent in time. Since blockchain technology allows for the creation of an immutable ledger, it may be used to keep track of a wide variety of financial and other types of transactions. Methodologies built into the system discourage the reporting of illegal transactions and ensure that everyone has the same understanding of what's going on.

Because of its decentralised and immutable nature, blockchain technology simplifies the process of documenting transactions and keeping track of assets in a corporate network. There are two primary types of assets, and they are the tangible and the intangible. Assets that can be seen, touched, and handled are considered physical assets. In contrast, intangible assets include things like intellectual property, patents, copyrights, and trademarks that can't be touched. Using a blockchain network for the monitoring and marketing of a broad variety of valuable assets, hence decreasing risks and costs for all parties involved.

Information and data are essential to the smooth operation of any firm. Due to its capacity to deliver real-time, readily distributable, and completely transparent data kept securely on an immutable ledger accessible only to authorised network members, blockchain technology is particularly successful in enabling the supply of information. Orders, payments, accounts, and manufacturing are just some of the many processes that the blockchain network can manage. In addition, thanks to the collective perspective of the group's participants, a clearer picture of the whole transaction process can be gleaned, leading to greater confidence and the birth of new efficiencies and possibilities.

**1.2 Importance and potential applications of blockchain-based solutions**

The distributed ledger technology known as blockchain facilitates the verification and tracking of transactions in multiple stages. It could potentially accelerate data transfers while assuring the security of all financial transactions. Contract management and product audits are two potential applications of blockchain technology. Key possible applications include the following:

**1.2.1 Transferring funds**

The original concept that inspired the development of blockchain technology retains immense practical value. Compared to the current system, blockchain-based money transfers may be quicker and less expensive. This is particularly true for international transactions due to the added time and cost involved. Compared to the days required by the current banking system in the United States, blockchain transactions take only minutes.

**1.2.2 Financial transactions**

In recent years, a multitude of new companies have emerged to offer decentralised Bitcoin exchanges. The distributed ledger technology enables affordable and more effective transactions. Moreover, a decentralised exchange maintains greater control and security because investors are not required to deposit funds with a central authority. Currently, blockchain-based exchanges only trade cryptocurrencies, but this could change in the future.

**1.2.3 Lending**

The lending institution is able to execute collateralized loans through blockchain smart contracts. Contracts stored on the blockchain can be programmed to activate upon the occurrence of specific events, such as the payment for a service, the issuance of a margin call, the complete redemption of a loan, and the release of collateral. Due to the decreased time and money required to process loans, banks can now offer more competitive interest rates.

**1.2.4 Insurance**

Smart contracts on a blockchain have the potential to increase insurers' and clients' transparency. If client claims were stored on a blockchain, consumers would not feel compelled to submit duplicate claims. In addition to accelerating the payment of claims, smart contracts help to expedite the process.

**1.2.5 Property investment**

To affirm ownership and finances and to transfer deeds and titles, real estate transactions require a multitude of documentation. Verifying and transferring real estate ownership may be safer and more convenient if transactions are recorded using blockchain technology. Possible advantages include shorter wait times, less documentation, and reduced costs.

**1.2.6 Personal information should be kept safe.**

Social Security numbers, birth dates, and other sensitive information may be safer on a public ledger (such as a blockchain) than in the hands of hackers. Tourism, healthcare, finance, and academic institutions, among others, may use blockchain technology to secure and expand access to personal data.

**1.2.7 Voting**

If voter registration records are stored on a blockchain, the technology will soon be utilised in elections. Using blockchain technology guarantees that only eligible electors may cast a ballot, that ballots cannot be tampered with, and that no individual may vote more than once. In addition, it has the potential to increase voter participation by making voting as easy as touching a few buttons on a smartphone. In addition, election costs would be significantly reduced.

**1.2.8 Government perks**

Welfare, Social Security, and Medicare are among the government programmes that could benefit from the use of digital identities stored on a blockchain. Blockchain technology has the potential to reduce fraud and operational expenses. Digital distribution based on blockchain technology may also increase the rate at which payments reach their intended recipients.

**1.2.9 Medical information should be shared in a secure manner.**

Through blockchain storage of medical data, physicians and other healthcare professionals may have access to accurate and current patient data. This may provide the greatest quality of treatment for patients who see multiple physicians. It could potentially expedite treatment by streamlining the process of accessing medical records. In addition, if insurance information is included in the database, physicians can readily determine if their patients are covered and if their care is covered by their policies.

**1.2.10 Artist remuneration**

To ensure that creators are compensated for their efforts, blockchain technology could be used to monitor the online distribution of audio and video assets. Blockchain technology has the potential to reduce piracy because it was designed to ensure that there are no redundant copies of content. Using a blockchain to monitor streaming service plays and a smart contract to distribute royalties could potentially result in increased openness and security.

**1.2.11 Tokens that are not fungible**

NFTs (or non-fungible tokens) are often considered a means of acquisition in the context of digital art. Due to the fact that data cannot exist in two locations at once on the blockchain, storing an NFT there guarantees that there will only ever be one copy of a digital work of art. This may make it comparable to purchasing physical art, but without the difficulties of maintaining its safety and security.

NFTs may be used for a variety of purposes, but at their core, they are simply a method to transmit possession of any digitally representable asset. This could be an event ticket, the broadcast rights to a film, or a property deed. The concept of an NFT is quite all-encompassing.

**1.2.12 Tracking logistics and supply chains**

Using blockchain technology to monitor items as they travel through a logistics or supply chain network may have numerous advantages. Since information is shared on a reputable public ledger, it is simpler to communicate. The impossibility of altering information stored on the blockchain enhances the security and integrity of the data. Therefore, logistics and supply chain partners may feel more at ease working together, knowing that the information they are exchanging is accurate and current.

**1.2.13 Networks for the Internet of Things that are secure**

The IoT is helping us in many ways, but it also opens the door for hackers to steal our information or take over our infrastructure. Blockchain technology might improve security since passwords and other private data would be stored on a distributed network rather than a central server. Additionally, protection against data tampering is provided by a blockchain's fundamental immutability.

**1.2.14 Storage of data**

The use of blockchain technology could increase the reliability of a data storage system. Unlike a centralised data storage provider, which may only have a few redundant points, it may be more difficult to infiltrate into a decentralised network and delete all the data. Due to the fact that it is not dependent on the actions of a single entity, it also indicates an increase in data accessibility. Blockchain data storage may be less expensive than alternative methods.

**1.2.15 Gambling**

The gaming industry may benefit from blockchain in numerous ways. Transparency is one of the most significant benefits of operating a casino on the blockchain, as it provides prospective participants with more information. Since every transaction is recorded on the blockchain, gamblers can see that the games are equitable and that the casino pays out. In addition, by utilising blockchain, no confidential information is required, such as a bank account, which may be a deterrent for some would-be gamblers. Participants can wager anonymously, and the decentralised network is not susceptible to government shutdown.

**1.3 Fundamentals of Blockchain Technology:**

**1.3.1 Introduction to Blockchain Technology:**

Blockchain is a method of preserving data that makes it difficult or impossible to alter, attack, or otherwise exploit the system. A blockchain is a distributed ledger that duplicates and replicates transactions across the network of computers involved. A network of peer-to-peer nodes connected by blockchain technology maintains public transactional data, also known as the "block," in multiple databases, also known as the "chain," within the system. This type of storage is commonly known as a "digital ledger." Each transaction in this ledger is validated and protected from deception by the owner's digital signature, which also serves to authenticate the transaction. Consequently, the data in the digital ledger is extremely secure. The digital ledger is a network of devices that share a Google spreadsheet containing transactional data corresponding to actual purchases. The intriguing aspect is that the data can be viewed by everyone, but cannot be altered.

**1.3.2 Distributed ledger technology and its features:**

Distributed ledger technology is a framework for assuring data security and accuracy through the use of ledgers maintained on numerous networked devices. In response to growing concerns about the proliferation of superfluous intermediaries in digital financial transactions, distributed ledgers were utilized to create blockchains.

Financial reporting, supply chain management, fraud prevention, and identifying inefficiencies are all areas where distributed ledger technology can be of great benefit to modern enterprises and organisations. As required, time and resources may be allocated to a variety of other business processes.

**Features:**

* Financial applications of distributed ledger technology are currently generating significant interest. Bitcoin's success as a cryptocurrency and as a proof of concept for DLT makes this conclusion logical. Financial institutions were early adopters of DLTs.
* Digital ledger technology (DLT) proponents assert that non-financial industries may also employ it. Government agencies are investigating technological methods for documenting transactions such as real estate title transfers. DLT is being evaluated by healthcare organisations as a more efficient method for updating patient data. Several companies are investigating DLT for supply chain data retention. And the legal industry is investigating how DLT can be utilised to process and execute legal documents.
* Experts concur that technological advancements that enable people to control who has access to their data, how long that data can be kept, and what data can be accessed result in increased privacy for individuals.
* Numerous individuals believe that digital ledgers could assist with the issue of keeping track of who possesses what intellectual property, such as novels, films, and other creative works.
* Although DLT adoption is still in its infancy, the technology has already demonstrated its ability to provide users with a variety of benefits, including: increased visibility into and transparency of data contributed to the ledger; lower operational costs due to the absence of a central authority; faster transaction speeds due to the absence of a lag in ledger updates; greatly reduced risks of fraud, tampering, and manipulation; and increased reliability.

**1.3.3 Blockchain consensus mechanisms**

A technique based on democratic consensus is used to maintain nodes in harmony. Thanks to decentralisation, all network users have an equal say in decision-making. Therefore, it is necessary to establish norms that all network elements must observe in order to concur on system modifications. The objective of the consensus mechanism of a decentralised network is to ensure that all nodes have an equal opportunity to update and validate network updates. To upgrade a decentralised network, pick the following version. Each node in a blockchain has access to the same immutable record of all network transactions.

**Proof of Work (PoW)**

PoW is a well-known consensus algorithm utilised by the Bitcoin and Ethereum networks. In this case, miners (or block adders) must conduct complex mathematical computations on the block's nonce in order to derive the correct hash. The miner who discovers a hash with a lower difficulty than the threshold will be permitted to submit his block to the network. In order to arrive at a conclusion in a puzzle-friendly manner, complex computations are used. Then, the preexisting network users who conducted valid transactions within the miner's block. Numerous cryptocurrencies employ the Proof-of-Work (PoW) algorithm, including Bitcoin, Ethereum, Dogecoin, Litecoin, Zcash, and Horizon.

**1.3.4 Smart contracts and their role in blockchain-based solutions**

Blockchain-based "smart contracts" (minimal computer software) are activated when certain conditions are fulfilled. Typically, they are used to automate the execution of a contract, providing immediate peace of mind to all parties without the need for a third party or additional time. In addition, they may programme the procedure so that the next phase is executed automatically when certain conditions are met.

A smart contract may include as many criteria as required to ensure the contentment of all parties involved. Participants must choose the format for recording transactions and associated data in the blockchain, concur on the "if/when...then..." principles that apply to those transactions, account for any potential exceptions, and devise a dispute resolution mechanism. A developer can then create the smart contract, while an increasing number of commercial blockchain users are turning to pre-built systems such as web interfaces and templates.

The primary benefit of smart contracts is the elimination of the need for third parties, analogous to the value of blockchain technology. The following are additional advantages of employing this method:

* They increase contract execution efficiency.
* There can be no human mistake.
* Immutability: The programming cannot be changed.

**1.4 Blockchain-Based Solutions in Financial Services:**

**1.4.1 Overview of blockchain in the financial industry**

* Blockchain enables the development of business networks that are more accessible, inclusive, and secure. It facilitates the adoption of standardised practises, the implementation of cost-saving innovations, and the development of innovative banking and financial services. Digital securities can be issued more swiftly, inexpensively per unit, and flexibly thanks to blockchain technology. Due to this, the market for investors may expand, issuers can save money, and counterparty risk in digital financial products can be reduced (Treleaven et al., 2017)
* In the past five years, blockchain technology has demonstrated the following benefits for enterprise-level applications:
* **Elimination of Single Points of Failure**: The distributed consensus architecture of Blockchain increases the system's security by eliminating potential vulnerable points such as centralised servers. This eliminates the need for inefficient monopoly utilities and other data intermediaries, such as transfer agents and messaging system operators.
* **Transparency**: Blockchain creates a more trustworthy and transparent network for all participants by utilising standardised protocols and shared processes. This permanent record facilitates communication, organisation, and consensus in a business system involving multiple parties (Javaid et al., 2022).
* **Programmability**: Due to their security and predictability, smart contracts are a type of automated business logic that can be created and executed on a blockchain. Consequently, the network's confidence and productivity increase.
* **Granular Data Privacy**: As a modern privacy solution, blockchain enables the selective sharing of data inside corporate networks. This protects people's privacy while increasing the system's openness, reliability, and efficiency.
* **Performance**: Due to their sophisticated architecture, both private and hybrid blockchain networks can handle a large number of transactions per second as well as transient spikes in network activity.
* **Scalability**: Thanks to blockchain's promotion of interoperability between private and public chains, any business solution can now leverage the global reach, robustness, and integrity of the main net.

**1.4.2 Cryptocurrencies and digital assets**

Bitcoin can be used to purchase and sell items, as a means of saving money, and as a unit of measurement. Even though cryptocurrencies lack intrinsic value, they are used to price other items. Bitcoin, which debuted in 2009, is commonly considered the first digital asset. It can be utilised as a currency or a speculative asset to determine its value. Crypto assets, also known as "digital assets," are monetary symbols made feasible by cryptography and the blockchain. Initially, they intended to make it simpler to transfer money without using banks or other well-known third parties. There are three different categories of crypto assets, including cryptocurrencies, crypto commodities, and crypto tokens. Stablecoins are new digital currencies backed by stable assets such as the U.S. dollar (Wang & Wu, 2021). They could have a significant impact on decentralised finance (DeFi). The term "digital assets" refers to all items created or exchanged on a blockchain. We divide digital products into five distinct categories. Cryptocurrencies, NFTs, and other tokens are no longer "emerging" technologies; they are now permanent components of the digital universe.

Blockchains are technologies that enable the production of digital products. They are peer-to-peer networks in which data is securely stored. Similar to public, shared files that are replicated across multiple computer systems, blockchains are replicated across multiple computers. This indicates that new records can be added, but existing records cannot be modified. A blockchain's recordings are its blocks. Each blockchain has its own standards for block creation. Each block contains information about the block that preceded it. This helps maintain the order and structure of the blockchain as it expands (Zhang & Fan, 2020).

When information is uploaded to a blockchain, a new digital object is created, or "coined." Users can trade their existing digital assets and create new ones (called "mint") using blockchain records.

**1.4.3 Blockchain-based payment systems and remittances**

Blockchain technology enables fast, secure, and inexpensive international payment processing services (and other transactions) by utilising encrypted distributed ledgers to provide trusted real-time transaction verification without the need for intermediaries such as correspondent banks and clearinghouses. While blockchain was initially developed to support Bitcoin, its potential applications beyond this digital currency are currently being investigated.

One may use blockchain payment systems to:

* Make it easier to settle deals.
* Maintain the transaction's validity in the absence of middlemen.
* Allow for peer-to-peer transfers or payments.
* Securely save the transaction details.
* Create a Bitcoin wallet and utilize it for payments as soon as possible.
* Such features of the blockchain payment system have also prompted banks to incorporate blockchain transactions into their systems and get the following benefits:
* Transactions should be made as simple as possible.
* Quickly settle them
* Remove middlemen from the payment system.

**1.4.4 Use cases of blockchain in banking and insurance**

Transaction, loan, mortgage, and payment services constitute the core of banking. Numerous of these products still employ obsolete techniques. The application process for a mortgage may take between 30 and 60 days, depending on the lender, while a business loan may take between 60 and 90 days, depending on the scale of the business. Blockchain technology may revolutionise the banking and lending sectors in order to reduce counterparty risk and reduce issuance and settlement times. In particular, it makes possible:

* Real-time financial document verification is made possible by authenticated paperwork and KYC/AML data, which also lower operational risks.
* Credit prediction and scoring marketplaces that are simplified, instantly informed by the collection of user behavior and authorized data over a network.
* Automated syndicate creation, underwriting, and fund distribution (principal and interest payments), which lowers syndication costs, delays, and friction.
* Collateralization of assets was made easier because of how real-time asset management, monitoring, and regulatory control enforcement are made possible by digitalization.

Claims for property and casualty insurance are notoriously time-consuming to process and frequently involve fraud. Blockchain has the potential to substantially reduce processing times by centrally and transparently administering data verification, claims processing, and distribution. In particular, it makes possible:

* Authenticated records and KYC/AML information lower the risk of fraud and make claim evaluations easier.
* processing claims automatically using smart contracts
* Automated parameterized contracts that pay out when a certain risk occurs
* Automated insurance payment distribution
* Tokenized reinsurance markets, which depart from conventional broker and relationship-based systems, enable policy reinsurance in open marketplaces.

**1.5 Blockchain Applications in Supply Chain Management:**

**1.5.1 Introduction to blockchain in supply chain management**

With the introduction of cutting-edge technologies such as artificial intelligence (AI), big data (Big Data), and blockchain (blockchain), proactive supply chain management is more crucial than ever. This article provides a thorough introduction to blockchain technology and discusses its most recent applications in the logistics industry. In the supply chain, blockchain technology may have multiple beneficial applications.

**Provenance tracking** - Frequently, the supply chains of large companies are intricate. This makes it more difficult for multinational corporations to keep track of their documentation. Without transparency, businesses run the risk of incurring substantial losses. Due to the incorporation of RFID identifiers and sensors in products, blockchain-based supply chain management facilitates record keeping and provenance monitoring.

**Cost reduction** - Utilising blockchain to monitor a product in real-time throughout the entire supply chain could reduce the overall cost of transporting goods. More than a third of supply chain experts polled by the Digital Supply Chain Institute cited cost reductions as the most significant advantage of incorporating blockchain technology into their operations.

In complex supply chains involving multiple stakeholders, mutual trust is essential for efficient operations. If a manufacturer shares its products with a supplier, for example, the manufacturer must be able to rely on the supplier to adhere to factory safety regulations (Chang & Chen, 2020).

**1.5.2 Traceability and transparency in supply chains**

Compliance with public and local government regulations is becoming increasingly essential for businesses, elevating the importance of supply chain management. However, most businesses have only a superficial understanding of their supply chain, even after travelling up or down the line one or two levels. There are three fundamental methods for enhancing supply chain visibility.

Traceability offers numerous advantages:

**Quicker problem-solving**: It makes it possible to determine what's causing issues with a certain drug or component and fix them. This is especially important during product recalls so that consumers and regulators can track down the cause of the issue. Companies may use this data to distance themselves from a crisis, saying things like "our food or product was unaffected," or to take remedial measures.

**Sourcing assistance**: Customers' expanding concerns about the origin and transport of the products they purchase present businesses with an opportunity to enhance their reputation through traceability.

**Improved operational procedures**: Traceability data can also be utilised to enhance planning and supply chain management. This could conceivably aid in several areas, including lead times, transportation costs, and stock management.

**An increase in sustainability**: Traceability's connection to the concept of supply chain sustainability is another crucial aspect. Related concepts include safety, security, the triple bottom line, and corporate social responsibility. With a transparent supply chain, businesses are able to inform all of their constituents, including customers, about the origins and production methods of their products.

**1.5.3 Blockchain-enabled inventory management and logistics**

Supply chain management depends primarily on inventory cost management. If there are insufficient products on board, the likelihood of a transaction decreases. Due to a dearth of basic materials, production will cease, there will be delays, and time and money will be lost. However, if dispatch periods were extended, costs would increase due to increased transportation costs and potential order cancellation penalties. As a result of escalating operational costs, businesses' profits will decline (Agi & Jha, 2022). It is impossible to manage inventory costs within the context of conventional supply channels. This article's primary objective is to present a blockchain-based method for clever inventory administration in the cloud industry. There are "multiple suppliers," "a manufacturer," and "multiple distributors" within the supply chain. The recommended models for inventory management incorporate a number of important costs. These include "transaction cost, inventory holding cost, shortage cost, transportation cost, time cost, setup cost, backordering cost, and quality improvement cost."

In a reactive model, supply and demand imbalances can take on a variety of forms. Customers may have moved on to another product by the time a company is ready to resupply a popular item. Companies spend a significant amount of money maintaining inventory. A related issue is what to do with all the excess inventory. Do we reduce the price of these items when we sell them? Should we redirect them to clearance centres, surplus retailers, or something wholly different?

A company may fail to satisfy demand if it produces insufficient quantities of goods. Every time they have to deal with dissatisfied consumers or run out of inventory, they lose money due to the inconvenience.

Blockchain-based distributed ledger technology (DLT) was created to assist consumer packaged goods (CPG) companies in keeping track of all the money that travels through their supply chain, from basic materials to finalised products to retailers. These files are accessible and storable by all network users. Businesses that deal with product provenance, traceability, potential recalls, and even perishable commodities with limited shelf lives may find this type of transparency and durability useful. Core to a Blockchain system is the streamlined, real-time exchange of data among its participants. Previously, it was difficult for producers to monitor consumer demand in such a timely manner. As a result, businesses can more accurately predict demand and plan ahead for production and replenishing, as opposed to simply reacting to stockouts. This ensures that they never have excess inventory and can always meet customer demand. In this optimal location, they can maximise revenue and profitability while minimising the risk of missing sales and storage expenses (Singh et al., 2022). Blockchain, in its most fundamental form, is a distributed digital ledger that tracks transactions across multiple processors in such a way that no single record can be modified retrospectively without influencing all subsequent blocks. In the field of logistics, this would imply that all paperwork pertaining to the transport and dispatch of a cargo would be maintained in a secure and unchangeable manner. This has the potential to significantly increase transparency and decrease bureaucracy, waiting time, mistakes, and deception.

**1.5.4 Smart contracts for automated supply chain transactions**

In addition to transparency, automation, security, and scalability, smart contracts may enhance supply chain management in numerous ways. Smart contracts enable all transactions and commodity movements to be recorded and documented on a shared ledger that can be validated by all parties, which may increase supply chain transparency, accountability, and traceability. By autonomously implementing predetermined actions such as releasing payments, transferring ownership, and sending out alerts, smart contracts can reduce human error, delays, and fraud while saving time and money. Using a smart contract, the terms of an agreement can be protected against manipulation and enforced. Encryption and digital authentication may be used to safeguard the data and the identities of the involved parties. In addition, smart contracts can manage vast transaction and data volumes, enabling for dynamic supply chain networks with complex structures. They may also integrate with other technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and the cloud, to improve the efficacy and effectiveness of supply chain operations.

When developing a smart contract for SCM, the business logic, data sources, security and privacy, testing and deployment, and other issues must be carefully considered. The smart contract should be adaptable and responsive to changing business requirements and circumstances, while capturing the underlying business logic and supply chain laws. Validating the quality and condition of products and services throughout the supply chain must also rely on accurate and trustworthy data sources. Prior to deployment, the smart contract must be rigorously tested and debugged to ensure its utility, stability, and compatibility. Protecting sensitive information requires the use of encryption, digital signatures, access control, and audit trails, as well as compliance with all applicable laws and regulations. A transparent and well-defined governance and maintenance framework should be in place to address any issues, shifts, or conflicts that may arise while the system is operational.

Multiple systems and industries are utilising smart contracts to enhance supply chain management (SCM). For instance, Walmart China and VeChain have collaborated to develop a monitoring platform for product safety. VeChain is a blockchain-centric SCM and business process platform. Mitsubishi collaborated with Skuchain, a blockchain platform that facilitates international trade finance, inventory management, and logistics, to expedite the provision of metal products and financing. The Co-op UK and Provenance are collaborating to educate consumers on the origins and environmental impact of their products. Provenance is a blockchain-based service that provides information about the origin, transportation, and ultimate disposition of an item.

Modern business transactions may benefit from smart contracts in a number of ways, including:

**Automation**: Contract terms may be executed automatically via smart contracts. By doing this, middlemen like banks, brokers, and attorneys are eliminated. The time and expense involved in contract execution may be greatly decreased as a result.

**Smart contract transparency**: Smart contract transparency. On the blockchain, the contract's terms and execution are visible to all participants. This may foster more trust and lessen the likelihood of disagreements.

**Security**: Because smart contracts are kept on a decentralized blockchain network, it is very difficult to alter or hack them. This offers a high degree of security and eliminates the need for oversight from a higher authority.

**1.5.5 Case studies of successful blockchain implementations in supply chains**

For companies looking to reduce issues connected to human error, blockchain is a revolutionary supply chain management tool. When human interference is eliminated via the use of cutting-edge technology like blockchain, more than 70% of supply chain executives, according to IBM, claim that speed, data quality, integrity, and visibility all significantly improve.

**AgriDigital**

One of the least digitized industries is agriculture, where farmers continue to preserve paper records of information like the medications given to animals. AgriDigital is a supply chain financier and supplier of agricultural commodities management platforms. It was established in order to build a blockchain-based verification system that would provide a solution for the digitization of agricultural processes and products. Consumers are curious about the goods' organic status, thus pertinent information regarding the product's growth phases and transportation is retained to make the product's origin transparent for consumers. Customers can now learn the organic state of their goods across the supply chain thanks to the use of blockchain technology.

**Fruit Distribution by Intel**

For the purpose of getting fresh fruits from the farm to the market, Intel partnered with a significant independent blueberry distributor. An integrated IoT solution was used for this, using Hyperledger Sawtooth Blockchain and Intel's Connected Logistics Platform.

The technology made it possible to monitor and audit the product's environmental conditions throughout its lifecycle, from harvest through distribution. Real-time control is provided over variables like temperature, humidity, light, etc. The technology made it possible to minimize freshness loss as a result.

**Techrock**

In order to reassure parents that their product is authentic, Techrock focuses mostly on baby formula. This is crucial for newborn formulae as they run the danger of melamine toxic contamination from dubious sources. To resolve this issue, Techrock employs intelligent packaging that enables smartphone verification of the product package's tag. A Hyperledger-based blockchain is in charge of each distinct verification tag. Therefore, this verification technique allows parents to verify the authenticity of their items.

**Walmart**

Walmart collaborates with IBM to ensure the security of their food supply chain, which is complex and difficult. Monitoring the freshness of food is extremely difficult due to the complexity of the supply chain. Contamination may result from a lack of temperature control throughout the distribution process. Perishable and fresh fruits and dairy products present an added difficulty. According to the Food Waste Index Report 2021 from the United Nations Environment Programme, 13% of global food waste occurs in the retail sector. Walmart employs blockchain technology to monitor the temperature of the transport unit when perishable products are being transported to circumvent these issues. This technique reduces the amount of time spent on paper-based food origin monitoring from days to mere minutes.

**World Wildlife Fund (WWF) and TraCeable Solutions Partnership**

Fishing may also be facilitated by blockchain. Customers expect businesses to adhere to ethical, sustainable, and humane practises whenever possible, including when capturing and processing seafood. Together, TraCeable and WWF will combat illegal fisheries. So that illicit or unethical fishing is less likely to be sold, their system is designed to collect harvest data such as location, capture records, crew information, etc. By scanning QR codes on fish packaging, consumers can access this blockchain-stored data.

TradeLens Maersk, one of the largest container transportation companies, employs IBM technology to monitor cargo in transit across the ocean in real time. The name of the company is TradeLens. TradeLens provides stakeholders with secure data exchange and anti-tampering capabilities in addition to real-time tracking of items throughout the supply chain. According to a case study conducted by IBM in the United States, TradeLens reduced by 40% the time it took for cargo to reach a production line, saving the company tens of thousands of dollars.

**1.6 Blockchain in Healthcare and Medical Records:**

**1.6.1 Overview of blockchain in healthcare**

Blockchain's decentralised ledger technology facilitates the secure transmission of patient medical records, improves the security of healthcare data, regulates the distribution of pharmaceuticals, and increases our knowledge of the human genetic code.

The use of blockchain technology in healthcare has the potential to stabilise healthcare costs, safeguard sensitive patient data, and enhance the quality of patient care. Existing applications include monitoring the spread of potentially fatal diseases and encrypting sensitive patient data.

Patients and physicians will both gain from these blockchain-based healthcare applications. Protection of medical records is the most prevalent blockchain healthcare application currently. Security is a significant concern in the healthcare sector. Between July 2021 and June 2022, 692 significant healthcare data intrusions were reported. The thieves stole credit card and banking information as well as data from health and genetic testing databases.

The immutability, decentralisation, and transparency of blockchain make it ideal for tracking sensitive medical data in secure applications. Blockchain technology has the potential to safeguard sensitive medical data because it is both private and transparent, concealing user identities behind multiple layers of encryption. The distributed nature of the system also enables the secure and confidential exchange of data between patients, physicians, and other members of the healthcare community (R et al., 2023)..

**1.6.2 Securing medical records and patient data using blockchain**

In the current information security landscape, both experienced and inexperienced hackers and intruders frequently target electronic data. The Electronic Medical Record (EMR) component of the Hospital Management System (HMS) must be secured immediately in order to protect patient information. This study proposes using blockchain containers operating on various channels to store individual patients' medical records. To accomplish this, we devised a custom BlockChain framework dubbed "Medichain" that integrates all of the necessary BlockChain components for securing patient data. Each node of the BlockChain maintains a database of patient records. In a decentralised, distributed, and definitive network, a user may choose to submit the file comprising the inventory of items as a JSON file. The proposed BlockChain Algorithm was implemented in Python and consists of a Merkle tree formulation, a proof of work, and a cryptographic hash of the records. The outcomes are extremely encouraging.

Chen et al. proposed a blockchain- and cloud-based storage solution and service architecture for the storage, sharing, and utilisation of medical data. Tanwar et al. proposed a Hyperledger-based system for the electronic exchange of medical records; however, scalability issues remain inevitable. Wang et al. introduced cloud-assisted electronic health record sharing to protect security and privacy via a consortium chain. Amofa et al. created a blockchain architecture that combines smart contracts with user-generated access mechanisms to accomplish PMHR security control in the transmission of medical and health records. Mikula et al. proposed a blockchain-based identity and access management system to govern authentication and authorization of users. This framework describes how the Hyperledger architecture uses blockchain technology for identity and access administration. Even though blockchain-based access management and storage for medical data have been incorporated in a variety of methods in these studies, the requirements of patients have not been explicitly considered (Tandon et al., 2020).

Omar et al. proposed the medical chain, a blockchain-based platform that utilises the distributed ledger technology's privacy and integrity protections for protected health information records (PHIR) in order to better safeguard patients' rights. The decentralised ledger technology (blockchain) employed by the medical records administration system guarantees the privacy of patients' medical history records (PHRs). Chen et al. proposed a blockchain-based, patient-centered paradigm with smart contracts governing hospital-wide access. By returning control to the patient, the PMHR has the potential to alter the existing healthcare hierarchy. Despite the emphasis placed on the patient as a consequence of this shift in authority, no specific instructions are provided for conducting experiments. A key management protocol based on blockchain technology has been released for healthcare databases with a patient-centric focus. This method will protect the patient's personal health record (PHR) encryption and decryption key pair. Gan et al. introduced a blockchain-based system for digital health system access control. The patient functions as an administrator in their system, granting the medical facility immediate and unrestricted access to the data. Institutions and other users alike will be required to submit an access request. Through the cloud server, the patient's information is also submitted to the blockchain.

**1.6.3 Interoperability and data sharing in healthcare systems**

This is crucial in a world where data security and dependability concerns are increasing as the number of connected devices proliferates. Additionally, the data proprietor can utilise smart contracts to selectively share data from multiple providers and treatment facilities. The triumph of Blockchain in the cryptocurrency market has piqued the interest of the healthcare industry. What delights healthcare professionals the most is this technology's capacity to address issues of trust, data integrity, and anonymization. Blockchain provides the foundation for a secure, permissioned framework for data exchange, but it does not resolve the underlying technological requirements for interoperability (Haleem et al., 2021).

Interoperability has been defined by the Healthcare Information and Management Systems Society (HIMSS). HIMSS identifies a continuum ranging from the lowest to the highest interoperability levels.

**Foundational** - At this stage, Health Information Technology (HIT) systems only communicate data without having the capacity to do so.

**Structural** – This is the intermediary layer that establishes the data formats used for communication across HIT systems while preserving the syntactic significance of the data.

Semantics is the top layer, where HIT systems exchange and receive data and use standardized codes to interpret the data in a meaningful way.

It's crucial that the EHR system satisfies all the aforementioned standards for true machine-to-machine interoperability. Along with the aforementioned technological prerequisites, data privacy is a major issue for healthcare stakeholders; as a result, any system enabling the interoperability of EHRs must enable permissions, trust, and data security.

Any technology that can safely address the issue of interoperability has the potential to alter the course of history. The potential of blockchain technology is as follows. It is not unexpected that it is sparking an excessive amount of interest in the sector. While companies like Health Level Seven International (HL7) still provide standards for data transmission, such as Fast Healthcare Interoperability Resources (FHIR), blockchain could offer the appropriate solutions.

**1.6.4 Clinical trials and research data management with Blockchain**

Medical records are collected, analysed, and archived so that they can be used to gain a deeper understanding of diseases, make new discoveries, and test research hypotheses. However, several obstacles impede the safe and efficient transmission of patient information:

Few individuals are aware of or have access to data sharing opportunities for clinical trials.

Low confidence in the safety of patients' private health information Low patient motivation to provide data

In electronic health records, issues with data interoperability and data aggregation are prevalent.

Ineffectively, the clinical trials research industry (pharmaceutical companies, research institutions, regulators, etc.) has endeavoured to resolve some of these issues in a variety of methods. Since the blockchain is both novel and highly disruptive, it may be the game-changing innovation required to resolve these issues. This innovative technology has the potential to substantially alter current business models and data storage, transfer, and sharing.

The innovative approach of blockchain technology to securing the storage and exchange of medical documents has the potential to generate new applications in the life sciences and health care industries. The financial industry has been at the forefront of blockchain's potential applications.

**1.6.5. Challenges and considerations for blockchain adoption in healthcare**

It is difficult to comprehend why the industry hasn't already worked out how to share patient data in a safe, dispersed manner given how many benefits it offers. But, like with many other things in the business world, there are certain specific reasons why it is difficult to exchange healthcare data. Before blockchain is adopted by the industry, I believe the following challenges must be resolved.

**A significant cultural change would be necessary**

Many physicians are still constrained by paper at the moment. Therefore, it is a tough ask to convince them to switch from paper records to electronic healthcare records (EHR) utilizing blockchain. For instance, physicians often leave questions blank since doing so is mandated by technology. The technology itself isn't that challenging; it's been created. However, change management is a significant task. For any sector, changing people's behavior is not a simple feat.

**Because healthcare is spread, implementation is challenging**

Regarding how various institutions manage records, healthcare physician providers and insurance payers vary widely. It would be very difficult to convince all of these organizations to utilize blockchain technology without a simplified method, like single payer. Unfortunately, the effectiveness of the whole system is diminished if any are unwilling to accept it.

**Some players are reluctant to provide information**

How insurance companies and hospitals intentionally work to avoid data sharing is a prime illustration of this. The confidentiality of cost information is a competitive advantage for hospitals. They can get varying fees for certain patients if they are required to cooperate with insurance companies. When these organizations are for-profit, it is challenging to exchange data.

**Governmental inattention**

We all know that making changes to the healthcare system in the United States is a contentious issue, and the Health and Human Services Administration would need to devote all of its attention to it as their priorities shift with each new President. So, how healthcare is administered actually relies on who occupies the White House. Four or even eight years are now insufficient to really effect the change; it will take at least ten years.

**The lack of a coordinating body to work on it**

Due to the decentralised nature of the healthcare system, no single entity can mandate its adoption by the rest of the industry. CHIME (The College of Healthcare Information Management Executives) is an organisation, but they have little influence. Last year, CHIME issued a request for a vendor willing to address the issue of patient identities. The main prize is one million dollars. I have not yet heard of anyone vying for the position. A million dollars may not be sufficient to surmount the dearth of effort for a system such as blockchain, which many individuals outside of IT have never heard of.

**1.7 Blockchain for Identity Management and Authentication:**

**1.7.1 Importance of identity management and authentication**

This is an example of identity management, also referred to as identity and access management (IAM). IAM is utilised in a variety of situations, including when an individual uses a computer for personal use and when an employee uses a computer for work.

Due to the numerous problems that older, less secure identity management systems caused, such as data breaches, widespread hacking, and the unauthorised sharing of sensitive information, regulations are becoming stricter regarding the collection, storage, use, and sharing of personal data.

**Secure identity verification:** Blockchain-based digital identification systems can rapidly and securely confirm a person's identity and credentials for a variety of reasons, such as establishing a bank account or gaining access to government services. Identity fraud and theft are prevented through blockchain-based identity verification, which increases security by doing away with the requirement for centralized third-party verification services.

**Healthcare data:** While healthcare practitioners may securely authenticate patient data and medical histories, patients can develop and control their own digital identities. This may lead to improved treatment while also protecting the security and privacy of data.

**Supply Chain Management:** Blockchain-based digital identities may be used to monitor and manage information about the supply chain, offering increased security and transparency. Supply chain managers may follow the flow of commodities across the supply chain by giving items digital IDs, assuring product authenticity and combating fraud and counterfeiting.

**1.7.2 Blockchain-based identity solutions and decentralized identity**

Businesses frequently hold sensitive user information alongside less sensitive routine business information. New business risks have emerged as a result of the increasing prevalence of user privacy-focused regulations such as GDPR and the industry's emphasis shift on corporate IT responsibility. This data is necessary for developing new products and obtaining a thorough comprehension of consumers, so it should not be stored in a secure location. Before committing to potentially hazardous and costly projects, many businesses will wait for either substantial penalties or increased IT resources in order to strike a balance between data security and business objectives. Three pillars support decentralised identity systems: the blockchain, Verifiable Credentials, and decentralised identifiers (DIDs). Among the expanding use cases for decentralised identity systems are employee ID administration, the dissemination of fraud-resistant certificates, and supply chain monitoring.

**1.7.3 Self-sovereign identity and user-controlled data**

Using a technique known as "self-sovereign identity" (SSI), individuals and institutions can administer their own digital identities and maintain the security of their data. Individuals with self-sovereign identities can retain their data locally on their devices and provide it for transactions and verification without relying on a centralised data repository. Users can manage and restrict access to their own confidential data if they have self-sovereign identity.

**1.7.4 Blockchain for digital identity verification and authentication**

Digital forms of identification and credentials make their utilisation easier for everyone. Among these are employee identification certificates, academic credentials, and professional licences. This private information must be protected, however.

The increasing prevalence of blockchain technology may be attributed to the fact that it is a tried-and-true method that can be utilised by governments, organisations, and educational institutions to provide a secure and dependable infrastructure and enhance services.

Digital forms of identification and credentials make their utilisation easier for everyone. Among these are employee identification certificates, academic credentials, and professional licences. This private information must be protected, however.

**1.7.5 Applications of blockchain in government services**

A blockchain-based digital governance may increase trust and accountability by safeguarding data, streamlining processes, and reducing waste, fraud, and abuse. Individuals, organisations, and governments aggregate their resources on a distributed, encrypted ledger within a blockchain-based governance model. Due to this architecture's elimination of a single point of failure, information belonging to individuals and the government is automatically protected from unauthorized access.

In addition to the possibility of addressing historical issues, a blockchain-based governance may offer the following benefits:

* Reduced use of labor-intensive procedures and secure data storage for the government, citizens, and businesses
* Lowering the exorbitant expenses of managing accountability
* Decreased risk of corruption and abuse
* Increased faith in civic systems online and in the government
* A wide range of governmental and public sector applications, such as digital currency/payments, land registration, identity management, supply chain traceability, healthcare, corporate registration, taxation, voting (elections and proxy), and management of legal entities, can be supported by distributed ledger technology.

**1.7.6 Blockchain-based voting systems and e-governance**

Online voting is gaining acceptance in contemporary society. There is a high chance that it will reduce administrative costs and attract more members. Voters do not need physical ballots or polling locations if they can vote from any computer with Internet access. Despite these advantages, online voting systems are studied thoroughly due to the additional risks they present. A single defect could permit widespread election manipulation. Electronic voting systems utilised in elections must be reliable, precise, secure, and practical. Nevertheless, the use of electronic voting systems may be hampered by a number of potential issues. To address these issues, developers created blockchain technology, which functions as a decentralised network for online voting today. Blockchain technology is an ideal candidate for use in the development of electronic voting systems due to the benefits of end-to-end verification. Due to its dispersed nature, non-repudiation, and security safeguards, this technology is an excellent replacement for conventional electronic voting systems. The following is an introduction to blockchain-based electronic voting methodologies. This study's primary objective was to assess the current state of blockchain-based voting research and online voting systems in order to discern potential future developments. This study provides an introduction to the blockchain's fundamental structure and characteristics as they pertain to electronic voting, as well as an overview of the theoretical application of blockchain technology for electronic voting. On the basis of the findings of this study, it would appear that blockchain technology may offer solutions to some of the issues presently impacting electoral processes. On the other hand, privacy and transaction times are frequently cited as concerns in relation to blockchain applications. A blockchain-based electronic voting system must accommodate both the rapidity of transactions and the security of remote participation in order to be scalable. Due to these issues, it became evident that the extant frameworks needed to be modified prior to their use in voting systems.

**1.7.7 Land registry and property rights on the blockchain**

**Digitization of Records:** The first step is to digitize existing land registry records. This includes property ownership, boundaries, transaction history, and any relevant legal documents.

**Blockchain Infrastructure:** These digital records are then stored on a blockchain network. It can be a public, private, or consortium blockchain depending on the jurisdiction's requirements.

**Immutable Records:** Once entered into the blockchain, property records are virtually tamper-proof due to the blockchain's immutability. This means that past records cannot be altered, providing a secure and transparent history of property transactions.

**Smart Contracts:** Smart contracts can be used to automate certain processes, such as property transfers. When predefined conditions are met (e.g., payment received), ownership is automatically updated on the blockchain.

**Accessibility:** Property records on the blockchain can be made accessible to authorized parties, including government agencies, property owners, and potential buyers. However, access levels can be controlled to protect sensitive information.

**1.7.8 Blockchain for transparent and accountable public finance**

Urban planning as a decision-making process requires familiarity with both the physical and social and cultural surroundings. As a result of advancements in mapping technologies such as GPS, remote sensing, GIS, UAVs, and the internet of things, we are now able to take more frequent, accurate, and convenient measurements of the physical world than ever before. These techniques generate the data necessary to describe a city's topography. To gain an understanding of the social and cultural landscapes, methods must be developed to capture the intuition of institutions (such as urban planning and environmental management organisations) and citizens, referred to as users in this paper, and incorporate that knowledge into the decision-making processes. Public participation in urban planning enables consumers (individuals and institutions) to actively seek optimal solutions to urban problems as part of the planning process.

**1.8 Adoption challenges and regulatory frameworks for Blockchain in government**

**Adoption Challenges:**

Unfortunately, many government institutions lack the knowledge and skills required to comprehend and implement blockchain technology effectively. Due to the compartmentalization of many government processes, it may be challenging to integrate blockchain technology into the current system. Due to their incapacity to expand, it may be difficult for blockchain networks to manage vast government activities. It may be difficult to safeguard private and confidential government data stored on a public blockchain. The adoption of blockchain technology by government entities is fraught with uncertainty. Bureaucratic inertia and resistance to change may hinder the government's ability to implement blockchain technology.

**Adoption Solutions in Blockchain:**

 Training programs and awareness campaigns can help government officials and employees grasp the technology's potential. Developing interoperable standards and protocols can facilitate seamless integration. Governments should explore blockchain platforms that offer scalability solutions or consider hybrid architectures. Utilizing permissioned blockchains with robust encryption and access controls can address this challenge. Governments should work on clear, flexible regulations that balance innovation with security and compliance. Encouraging a culture of innovation and streamlining bureaucratic processes can help overcome resistance.

**Regulatory Frameworks in Blockchain:**

Governments should officially recognize blockchain and smart contracts as valid forms of technology and contracts, providing legal clarity. Regulations should mandate strict data protection and privacy measures for blockchain-based systems, especially when handling citizens' personal data. Establishing a legal framework for blockchain-based digital identities can enhance security and reduce identity fraud. Governments should develop regulations that define the legal status of smart contracts, enforceability, and dispute resolution mechanisms. Clear guidelines on the taxation of cryptocurrency transactions are essential for both government revenue and blockchain businesses. Implement AML and KYC regulations to prevent illicit use of blockchain technology while ensuring compliance with financial laws. Develop regulations around the tokenization of physical and digital assets to enable secure and legal trading. Establish international agreements and standards for cross-border blockchain transactions to facilitate global governance. Develop frameworks for blockchain network governance, including the role of validators, miners, and consensus mechanisms. Ensure that government agencies can audit blockchain systems for compliance with regulatory standards.

**1.9 Blockchain-Based Solutions in Other Industries:**

**1.9.1 Blockchain in energy and renewable sectors**

In the energy industry, there is still some justifiable skepticism and resistance to the use of Blockchain technology. Since safety, efficiency, and scalability are at stake, this situation requires long-term investment and value. Until individuals involved in the adoption process are persuaded of the advantages of a new technology, its widespread adoption will not occur. The widespread adoption of Blockchain technology is improbable unless business executives are persuaded that it is the definitive answer to all of their security issues. When implementing Blockchain in the energy industry, gaining people's trust in the technology may be the most difficult obstacle.

As a result of inefficient and unsustainable pricing mechanisms, Blockchain also struggles with the administration of utility income. If peer-to-peer transactions are to increase grid efficacy, for instance, shared distribution infrastructure must be preserved. It is difficult to conceive of a scenario in which the utility in command of the distribution network would earn a portion of every Blockchain transaction, but it is conceivable.

The lack of well-defined international laws is an additional significant barrier to Blockchain applications in the energy sector. Future decentralized energy systems will include significant infrastructure, power costs, conflicts, and transaction reversals; therefore, rules will be necessary to govern them.

**1.9.2 Blockchain for intellectual property and copyright protection**

Only recently is the complete potential of blockchain technology becoming apparent. We have made some educated estimates regarding the potential applications of blockchain and distributed ledger technology in numerous industries, including voting, environmental, social, and governance (ESG), and production. As the prevalence of NFTs has increased, more people have begun to legitimately worry about how to protect their intellectual property. Perhaps blockchain technology is the answer to achieving this security. Generally, absolutely. In this manner:

Let's begin with the main issue. An individual is the sole proprietor of his or her creative output. You may have spent considerable time on this, but attempt to envision someone else passing it off as their own work. There is no doubt that this causes some anxiety. Disputes regarding copyright or intellectual property claims were formerly resolved through arbitration. As more individuals had a stake in the outcome, the resolution procedure carried on.

The architecture of Blockchain permits the decentralized recording of data transactions. This generates a decentralized system with a transparent and immutable ledger. Even though research into blockchain's potential applications for IP protection and related fields is still in its infancy, we already know that it can be of great assistance in a number of different fields.

**1.9.3 Blockchain applications in the legal industry**

There are several possible blockchain applications across the legal industry. Here are some of the top use cases that ConsenSys has identified:

* Electronic Signatures
* Intellectual Property
* Property Rights
* Chain of Custody
* Tokenization
* Decentralized Autonomous Organizations (DAO)
* Limited Liability Autonomous Organizations (LAO)
* Automated Regulatory Compliance
* Machine to Machine Payments
* Blockchain-Based Arbitration System

**1.9.4 Blockchain for supply chain sustainability and ethical sourcing**

Due to the accelerated rate of environmental degradation and depletion of natural resources, the academic community has shifted its focus from economic to socio-environmental concerns. Blockchain is revolutionary because it can reorganize the supply chain from the ground up in order to prioritize environmentally favorable practices. Blockchain, a distributed ledger technology, provides a digital database for documenting and validating all business transactions along a supply chain. This research's primary objective is to conduct a literature review on blockchain technology as it relates to environmentally responsible supply chain management. This study investigates the governance, social equality, and environmental sustainability of a blockchain-powered supply chain. 136 articles were evaluated and divided into categories according to the three dimensions of sustainability using a methodical literature review. The application of blockchain technology in the apparel, transportation, food production, manufacturing, automotive, and healthcare industries has been thoroughly scrutinized and analyzed. New developments in a circular supply chain, as well as the critical success factors for each, were highlighted, and the economic, environmental, and social effects of blockchain were investigated. In addition, there are suggestions for future research and a summary of the assets and weaknesses of the existing literature. The findings of this study indicate that blockchain technology has the potential to revolutionize the entire supply chain from a sustainability standpoint. In addition to improving the economic sustainability of the supply chain through effective traceability, increased visibility through information sharing, transparency in processes, and decentralization of the entire structure, blockchain will contribute to social and environmental sustainability through resource efficiency, accountability, smart contracts, and fraud prevention. The study's findings will assist managers and practitioners in gaining a deeper understanding of blockchain's adoption process and will increase the likelihood of the technology's successful application in the development of a resilient supply chain network.

The number of applications for digital product passports continues to rise, but many high-end companies may struggle to determine where and how to implement them most effectively. Protokol provides blockchain consulting, NFT consulting, Web3 consulting, and blockchain engineering services to assist businesses in identifying areas where a digital passport solution could truly add value to their operations and contribute to the delivery of the promise of sustainable luxury.

As a business blockchain service provider, we assist luxury-goods manufacturers in enhancing the customer experience with digital product passport solutions that ensure their products are sustainably and ethically sourced, while simultaneously opening up new revenue streams.

We can design digital passports that are adaptable, secure, interoperable, and compatible with your current IT infrastructure. In addition to utilizing blockchain technology to affirm ethical sourcing practices, our products include extensive tools for verifying the origin, transfer history, and provenance of a product. All of which increases consumer loyalty to your brand and encourages further growth.

**1.9.5 Future trends and emerging use cases of Blockchain technology**

Even though it took the introduction of cryptocurrencies for blockchain technology to gain widespread recognition, the world is now aware of its other significant applications. Emerging blockchain innovations in 2023 will radically alter the international business landscape. This robust database technology is not only the foundation of cryptocurrencies, but also provides so much value to businesses that PwC predicts it will add $1.76 trillion to the global GDP by 2030.

This is because blockchain is an indispensable instrument for modern enterprises that rely on transactions. Significant contributing factors include the fact that it streamlines transactional verification, provides comprehensive security measures, and enhances data privacy and protection.

Let's examine the most intriguing developments in the blockchain space in 2023, as well as the current state of this cutting-edge technology.

The answer to your query is "yes" Despite setbacks such as the "crypto winter" and the impending extinction of algorithmic "stablecoins" in 2022, the blockchain industry is still in its infancy and poised for explosive growth. In 2023, the impact of blockchain technology on society and the economy is anticipated to increase. As more individuals and organizations recognize the advantages of Web3 technologies such as blockchain, 2018 will be a transformative year. Numerous well-established industries, such as banking, finance, supply chain management, healthcare, and cybersecurity, stand to gain significantly from blockchain technology.

**Conclusion:**

In conclusion, blockchain-based solutions are a game-changing technology that has the potential to revolutionize entire industries by improving security and expediting processes. They do, however, face some obstacles. Scalability, security, regulatory constraints, and interoperability must be addressed in order for blockchain to realize its maximum potential.

However, blockchain presents a multitude of opportunities. The potential applications are numerous and thrilling, including enhancing supply chain management, launching decentralized financial ecosystems, and granting individuals control over their identities. It is evident that blockchain has the potential to bring transparency, efficiency, and confidence to numerous industries.

It is essential that blockchain's creators, entrepreneurs, and legislators collaborate to surmount the technology's obstacles and capitalize on its potential as it continues to develop and evolve. With continued investment in its development and a commitment to responsible adoption, blockchain has the potential to become a defining technology of the modern era, revolutionizing how we conduct business, safeguard our data, and communicate in a globalized world.

**References**

Treleaven, P., Gendal Brown, R., & Yang, D. (2017). Blockchain Technology in Finance. *Computer*, *50*(9), 14–17. https://doi.org/10.1109/mc.2017.3571047

Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Khan, S. (2022, July). A review of Blockchain Technology applications for financial services. *BenchCouncil Transactions on Benchmarks, Standards and Evaluations*, *2*(3), 100073. https://doi.org/10.1016/j.tbench.2022.100073

Wang, R., & Wu, Y. (2021, March 31). Application of Blockchain Technology in Supply Chain Finance of Beibu Gulf Region. *Mathematical Problems in Engineering*, *2021*, 1–10. https://doi.org/10.1155/2021/5556424

Zhang, L., & Fan, D. (2020, December). Analysis of the Application of Blockchain Technology in the Financial Industry. *2020 International Conference on Big Data Economy and Information Management (BDEIM)*. https://doi.org/10.1109/bdeim52318.2020.00033

Chang, S. E., & Chen, Y. (2020). When Blockchain Meets Supply Chain: A Systematic Literature Review on Current Development and Potential Applications. *IEEE Access*, *8*, 62478–62494. https://doi.org/10.1109/access.2020.2983601

Agi, M. A., & Jha, A. K. (2022, May). Blockchain technology in the supply chain: An integrated theoretical perspective of organizational adoption. *International Journal of Production Economics*, *247*, 108458. https://doi.org/10.1016/j.ijpe.2022.108458

Singh, C., Thakkar, R., & Warraich, J. (2022, October 14). Blockchain in Supply Chain Management. *European Journal of Engineering and Technology Research*, *7*(5), 60–69. https://doi.org/10.24018/ejeng.2022.7.5.2888

R, G., Ranagatti, J. V., S M, L., Sangamad, L., & J, D. N. (2023, January 31). A Literature Review of Blockchain Applications in Healthcare. *International Journal for Research in Applied Science and Engineering Technology*, *11*(1), 1338–1346. https://doi.org/10.22214/ijraset.2023.48808

Tandon, A., Dhir, A., Islam, A. N., & Mäntymäki, M. (2020, November). Blockchain in healthcare: A systematic literature review, synthesizing framework and future research agenda. *Computers in Industry*, *122*, 103290. https://doi.org/10.1016/j.compind.2020.103290

Haleem, A., Javaid, M., Singh, R. P., Suman, R., & Rab, S. (2021). Blockchain technology applications in healthcare: An overview. *International Journal of Intelligent Networks*, *2*, 130–139. https://doi.org/10.1016/j.ijin.2021.09.005