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ABSTRACT

Design/methodology— The research began with an in-depth review of the academic literature on blockchain adoption in supply chain management, addressing various pressures influencing Block chain technology adoption in enterprises and identifying a gap related to the perceived improvement in transparency and performance of the supply chain affecting the intention of adoption of block chain technology, rather than the measurable outcomes. To address this, a structured questionnaire was administered to a diverse international sample of professionals across various industries. The collected data were analyzed using PLS-SEM (Partial Least Squares Structural Equation Modeling), to test a conceptual model grounded in the Technology–Organization–Environment (TOE) framework.

Findings – – The findings highlight that perceived transparency and performance significantly influences trust, which in turn mediates the intention to adopt blockchain technology. Top management support emerged as a strong driver of adoption, while trading partner pressure was found to have a marginal influence. The model also confirmed the reliability and validity of the constructs used, with good levels of explained variance (R^2) and significant path coefficients. Overall, the study emphasizes the psychological dimension of technology perception, particularly trust and transparency, as a critical enabler of blockchain adoption.

Practical implications – The results provide actionable insights for organizations considering blockchain implementation in their supply chains. Specifically, they highlight the importance of cultivating an internal culture of trust, ensuring executive-level support, and aligning blockchain solutions with existing IT systems to enhance interoperability and perceived transparency. These findings can guide managers in designing more effective adoption strategies based on human and organizational readiness.

Research limitations –The study is limited by its sample size and the cross-sectional nature of the data, which captures perceptions at a single point in time. Although the survey reached an international audience, certain industries or regions may be underrepresented.

Originality/value – This study contributes to the blockchain adoption literature by focusing on the perceptual and psychological drivers of adoption intention, rather than technical or financial performance. By integrating TOE theory with a user-centered view of perceived transparency and trust, the research offers a novel conceptual and empirical framework for understanding blockchain as a strategic tool for supply chain transformation. The originality lies in shifting the lens from technological capability to human perception within organizational decision-making.

Keywords – Blockchain, Transparency, Trust, Pressure, Block chain Adoption, Supply Chain Management, Top management support, TOE Framework, PLS-SEM

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INTRODUCTION

This thesis reviews the existing literature on blockchain technology, analyzes some variables that influence its adoption and considers its potential in supply chain management (SCM). In recent years, blockchain technology has emerged as one of the most transformative innovations across various sectors, with particular significance in Supply Chain Management (SCM). Originally conceptualized as the underlying architecture of Bitcoin in response to the 2008 financial crisis, blockchain was designed to counteract the opacity and centralized control of traditional financial systems. Since its inception, it has evolved into a versatile digital infrastructure that offers decentralization, immutability, traceability, and transparency, core features that have positioned it as a strategic enabler for modern supply chain ecosystems (Shi Dong, 2023); (Gautami Tripathi, 2023); (Wang, 2021). Supply chain operations have historically been challenged by fragmented data systems, limited visibility, and trust issues among stakeholders. As noted by (John T. Mentzer W. D., 2001), SCM should be regarded not merely as a set of logistical practices but as a strategic framework that demands inter-organizational coordination, process integration, and customer-centric value creation. Within this complex and dynamic context, blockchain offers the potential to address long-standing inefficiencies by introducing a secure and decentralized ledger that facilitates real-time data sharing, automated transaction validation, and tamper-proof recordkeeping. While substantial scholarly attention has been given to the technical benefits of blockchain, such as enhanced transparency, real-time monitoring, and smart contract automation, this thesis aims to explore also a less examined dimension: the psychological perception of improvement brought by blockchain adoption. Most of the existing literature focuses on the measurable outcomes of blockchain implementation, such as operational efficiency or cost savings (Kshetri, 2018); (Chitra Lekha Karmaker, 2023). However, decision-making within organizations often hinges not only on quantifiable performance metrics but also on subjective judgments, expectations, and perceived value. This thesis therefore puts the analytical lens also toward understanding how perceived improvements, particularly in transparency and performance, influence the intention to adopt blockchain. Anchored in the Technology–Organization–Environment (TOE) framework, the study integrates both external and internal pressures, such as competitive pressure, trading partner pressure, and top management support, with psychological variables like perceived supply chain transparency and performance improvement. The research design combines theoretical rigor with empirical analysis, employing a survey-based methodology and Partial Least Squares Structural Equation Modeling (PLS-SEM) to validate the conceptual model and assess the relationships between the proposed variables. The results underscore the importance of perceived transparency and trust as mediators in the adoption process. Unlike traditional models that prioritize cost-benefit analysis or technological readiness, this study identifies perception-driven enablers as critical determinants of adoption intent. Furthermore, the findings reveal that top management support plays a pivotal role, while trading partner pressure exerts only marginal influence. The analysis offers both theoretical and practical contributions, suggesting that the subjective perception of value, rather than just the objective technological capability, may determine whether an organization chooses to adopt blockchain. This research is particularly relevant in the context of global disruptions, such as the COVID-19 pandemic and geopolitical instabilities, which have exposed vulnerabilities in traditional supply chains (WIELAND, 2021). The evolving nature of supply chains, from linear models toward resilient, adaptive, and transparent ecosystems, necessitates a reassessment of how technological innovations like blockchain are perceived and integrated. By examining the intention to adopt blockchain through both organizational and psychological perspective, this thesis seeks to enrich the discourse on digital transformation in supply chains and offer insights into how perception shapes strategic technology adoption.

This thesis is organized as follows: the first section will cover an extensive literature review on blockchain technology and its applications in SCM, followed by an exploration of the six key variables analyzed. The second section presents the empirical study, detailing the research design, methodology, and data analysis. The final chapters discuss the findings, outline practical implications, and offer theoretical contributions, along with limitations and recommendations for future research. In doing so, the thesis contributes a novel perspective to blockchain adoption literature, one that elevates the role of perception in the strategic evaluation of emerging technologies.

SECTION 1: LITERATURE REVIEW

CHAPTER 1: Blockchain Technology

1.1 Genesis of Blockchain

While comparable data structures have existed for years, blockchain technology was formally conceptualized and defined in 2008. (Shi Dong, 2023) and officially came into being on January 3, 2009, with the invention of Bitcoin. In fact, Blockchain emerged as a response to the 2008 financial crisis, which was caused by a financial system characterized by opacity and the dominance of a small elite . Looking beyond the financial world, Blockchain was created to provide individuals with a digital tool that is secure, transparent, decentralized, and disintermediated. Since the creation of the first cryptocurrency, numerous experiments and studies have been conducted on existing platforms and use cases. The year 2016 was marked by a major wave of media hype. The press began to report on Blockchain, and the idea spread that it could become one of the technologies capable of revolutionizing the digital space. Soon after, there was a surge in Blockchain projects, often accompanied by ICOs (Initial Coin Offerings). Once the media frenzy subsided, a drastic collapse in cryptocurrencies followed. This period would later be remembered as the "Crypto Winter", during which many projects failed and ICOs faced numerous regulatory hurdles and difficulties in development. In 2020, however, various initiatives were undertaken by central banks and governments. Experiments accelerated regarding the issuance of Central Bank Digital Currencies (CBDCs), and the European Commission worked within the Finance Digital Package on regulations for crypto assets. In 2021, the decentralized finance (DeFi) sector grew, while crypto-assets gained importance thanks to the adoption by several financial institutions and the renewed popularity of the NFT phenomenon. In 2022, the term Web3 became widespread, and there was continued growth in applications built on public platforms. Despite the cyclical media hype, we observe a constant evolution of Blockchain. The adoption of this technology continues to grow steadily and, year after year, attracts investments from all around the world. Blockchains are not ordinary registers; rather, they incorporate unique properties capable of offering various opportunities within the business domain. The core values behind Blockchain technology fully reflect the motivations for which it was originally conceived.

In fact, Blockchain emerged as a response to the 2008 financial crisis, which was caused by an opaque financial system dominated by a select few. Looking beyond the financial world, Blockchain was created to provide individuals with a digital tool that is secure, transparent, decentralized, and disintermediated.

The Blockchain landscape is highly diverse, each platform possesses its own strengths and unique characteristics. Nevertheless, it is possible to identify six key features shared by most existing Blockchains. The first naturally refers to **digitization**, or the transformation of data into digital format. Below are the remaining five characteristics that make this technology particularly **secure and reliable**:

Decentralization : Information is recorded by distributing it across multiple nodes, ensuring cybersecurity and system resilience.

Disintermediation: Platforms allow transactions to be managed without intermediaries, meaning without the need to rely on a third party.

Transparency and Verifiability: The contents of the ledger are transparent and visible to all, and can be easily consulted and verified.

Programmability of Transfers: It is possible to program specific actions to be executed upon the occurrence of predetermined conditions.

Immutability of the Ledger: Once data is written to the ledger, it cannot be modified without the consensus of the network.

1.2 Evolution of Blockchain technology

Blockchain technology has significantly transformed the digital landscape of contracts, transactions, and records—forming the backbone of economic, political, social, and legal systems worldwide. Its development can be categorized into four generations:

First Generation: Initiated with the introduction of Bitcoin in 2008 by the pseudonymous Satoshi Nakamoto, marking the advent of blockchain and cryptocurrencies in digital financial transactions.

Second Generation: Saw the implementation of smart contracts, expanding blockchain functionality beyond monetary transactions to encompass financial instruments such as stocks, loans, and smart property.

Third Generation: Extended blockchain use to sectors beyond finance, including healthcare, governance, and scientific research.

Fourth Generation (emerging): Envisions the integration of blockchain with Artificial Intelligence (AI) and digital intelligence for advanced and autonomous applications.

The exponential rise in blockchain adoption is evident through notable historical events—for example, in 2010, developer Laszlo Hanyecz purchased two Papa John's pizzas for 10,000 Bitcoins, worth approximately $30 at the time. By 2018, the same Bitcoins were valued at over $80 million, underscoring the dramatic growth of blockchain technology and cryptocurrency markets. Today, with analysts like Standard Chartered's Geoffrey Kendrick forecasting Bitcoin to reach $200,000 by the end of 2025—driven by macroeconomic catalysts such as potential Federal Reserve rate cuts and increased institutional interest—the narrative around Bitcoin has shifted from speculative asset to long-term digital store of value, further cementing its role in the evolving financial landscape (Merchant, 2025).

1.3 Blockchain Architecture

In a blockchain system, data is structured into blocks through the use of specific hashing algorithms and data structures, such as Merkle trees or binary hash trees. Each node within the distributed network processes the transaction data it receives by encoding and packaging it into data blocks. These blocks are then timestamped and sequentially linked to the longest main chain. This process incorporates several technical components, such as blocks, chain structures, hashing mechanisms, Merkle trees, and timestamps, which collectively ensure the secure, verifiable, and chronologically consistent organization of data across the blockchain (Gautami Tripathi, 2023).

Block

Blocks serve as data containers that encapsulate digital information, including transactions, timestamps, and cryptographic elements. Each block is composed of a header and a set of transactions. The header contains metadata such as the hash of the preceding block, a timestamp, a nonce, and the Merkle tree root. Fig. 1 and fig 2 show the basic structure of a block.

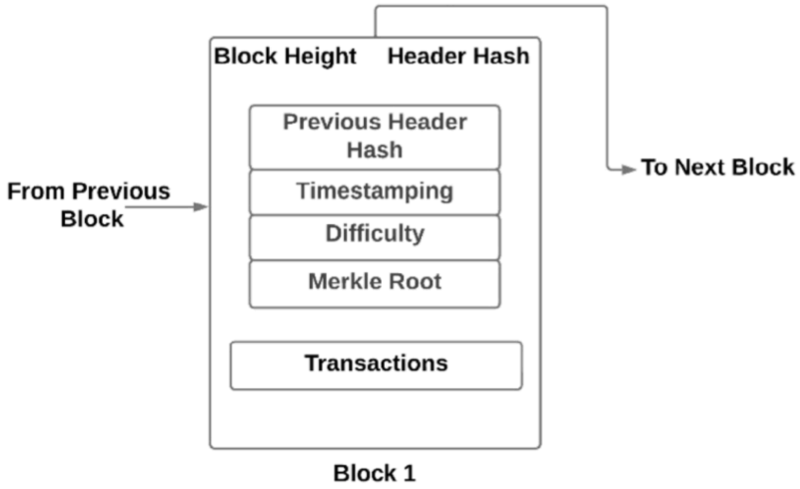

Figure 1 block structure by (Gautami Tripathi, 2023)

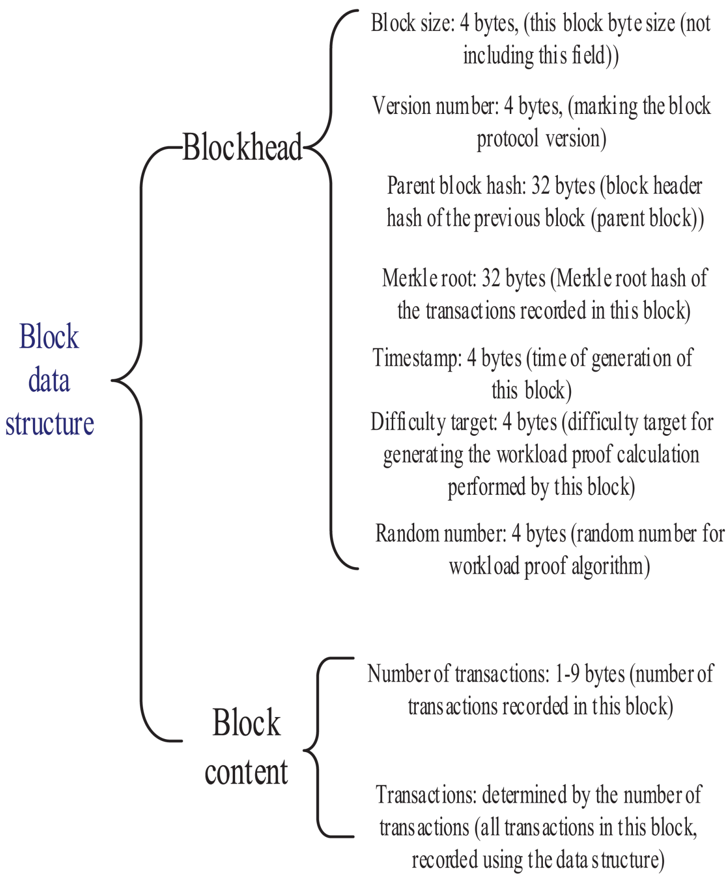

Figure 2 block structure by (Shi Dong, 2023)

A block is identified using either the block hash or the block height. Block hash is the hashID of the block that is generated while the block height defines the positioning of the block in the block chain.

Merkle tree

The Merkle tree is a fundamental component of blockchain architecture, acting as an essential data structure that facilitates the efficient verification and summarization of block data integrity (Borde, 2022). Its core purpose is to allow for the identification and traceability of every transaction within a block, thereby enabling their precise location across the blockchain. Blockchain systems typically implement a binary tree variant of the Merkle tree to organize and condense transaction data. This approach generates a unique cryptographic fingerprint representing the entire set of transactions within the block. A visual representation of this structure is provided in Figure 3.

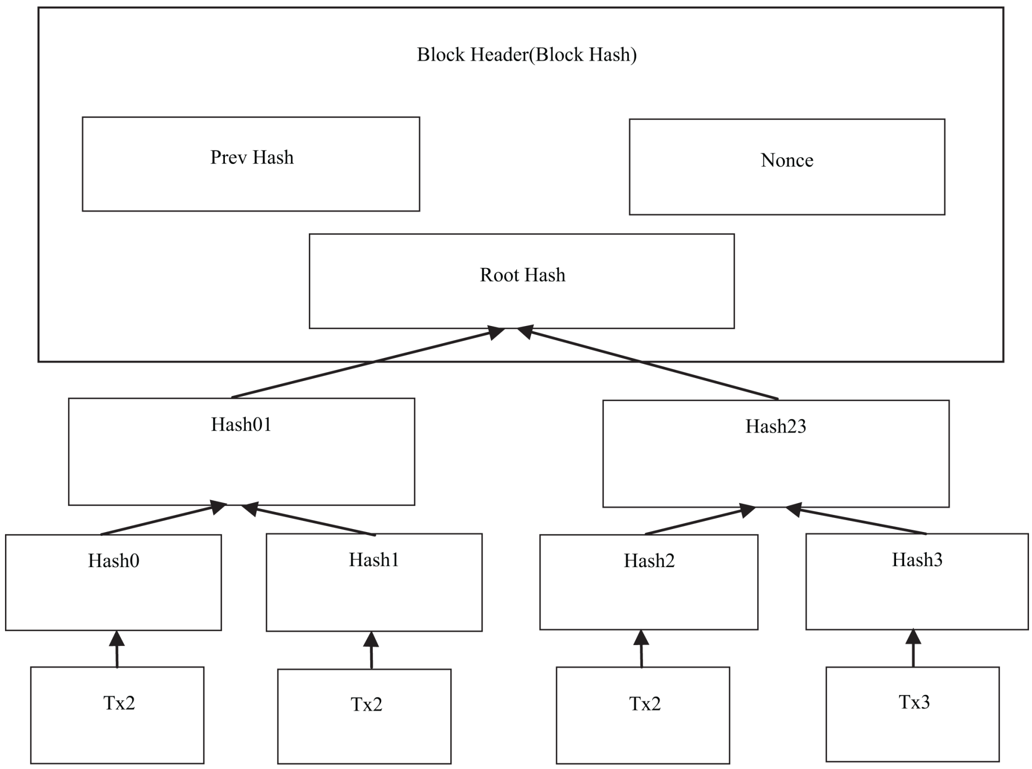

Figure 3 by (Shi Dong, 2023)

Therefore, merkle tree gives the digital fingerprint of the entire set of transactions. These blocks are linked together to form the blockchain structure. The block header contains a field to store the hashID of the previous block in the chain (Gautami Tripathi, 2023). Fig. 4 shows the arrangement of blocks in a blockchain.

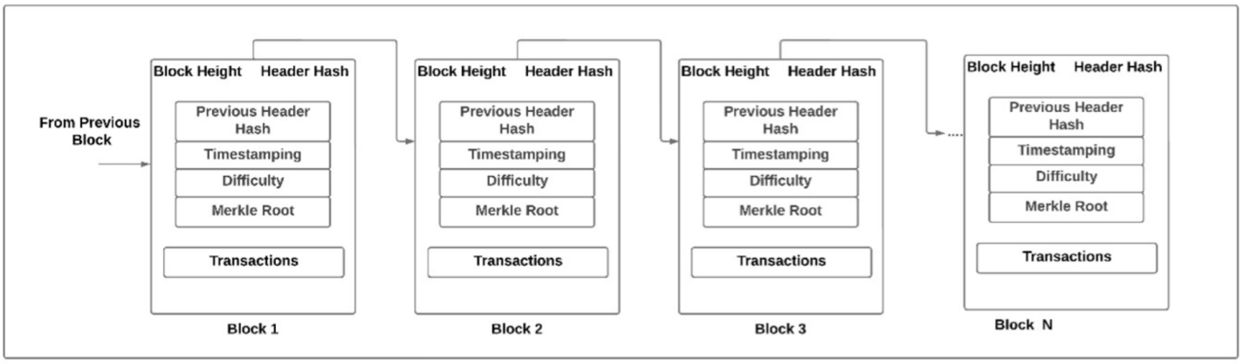

Figure 4 by (Gautami Tripathi, 2023)

Timestamp

In blockchain technology, nodes with bookkeeping privileges are required to include a timestamp in the header of the current data block. This timestamp indicates the exact time when the block was written or added to the blockchain. By incorporating this timestamping mechanism, the blockchain ensures that blocks on the main chain are arranged in a chronological order, reflecting the sequential

order of transactions. Timestamps play a key role in reinforcing the blockchain's resistance to tampering. If any data within a block is altered, the discrepancy between the original timestamp and the altered data's timing would expose the unauthorized modification. This temporal sequencing, combined with the immutability of records, significantly strengthens the blockchain's security and ensures the integrity of the data stored within the system (Shi Dong, 2023).

When a user initiates a new transaction through their wallet application, the request is broadcast across the blockchain network. This transaction enters a pool of pending, unconfirmed transactions, from which miners select entries to include in the next block. These selected transactions along with relevant metadata are the components of a new block. Then the miners compute a valid hash for the block and share it with the network, including its digital signature. The remaining nodes verify the block's authenticity by validating the signature. Once verified, the network reaches a consensus to incorporate the block into the blockchain. Each subsequent block added to the chain acts as a confirmation of the previous one, reinforcing its legitimacy. (Gautami Tripathi, 2023) Fig. 5 presents the process of the addition of blocks in the blockchain.

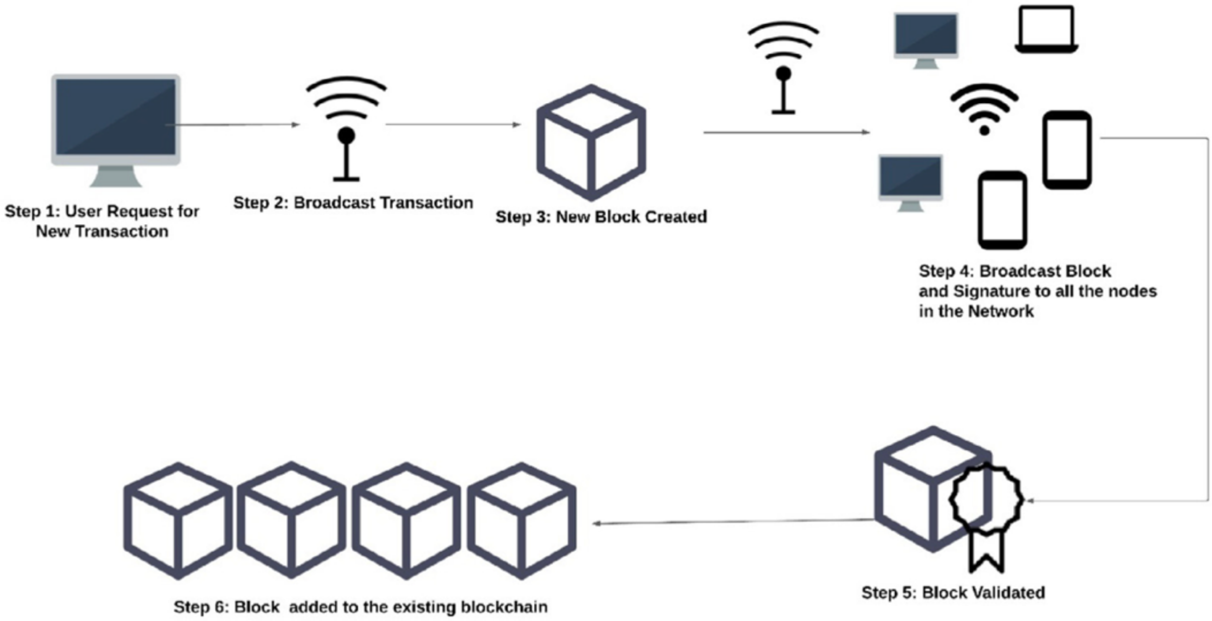

Figure 5 process of addition of blocks in the blockchain

1.4 Fundamentals of Blockchain Technology

Wallets

Blockchain wallets are essentially *"signing devices"* that allow users to store tokens and cryptocurrencies and perform transactions on the Blockchain. Whether referring to individuals or companies, wallets store users' **private keys**. Blockchain accounts are composed of a **public key** (comparable to an IBAN), a **private key** (similar to a password), and a **seed phrase** (or recovery phrase). To initiate a transaction on the Blockchain, the user or company uses their wallet to sign it using their private key. There are various types of wallets and different possible configurations. The primary distinction is between **custodial** and **non-custodial** wallets:

• **Custodial Wallets**: The wallet's keys are managed by a third party. The user relies on the provider to operate the wallet, without the burden of directly managing private keys.

• **Non-Custodial Wallets**: These wallets are managed directly by users, who thus become the sole holders and responsible parties for their wallets.

The most significant difference between these two approaches lies in the actual control over the assets. This concept is often summarized by the well-known mantra: **"not your keys, not your coins."** This phrase, frequently used in the Blockchain ecosystem, conveys the idea that in the case of a custodial wallet, the user cannot be considered the direct owner of the assets, as control is exercised by third parties. (Gautami Tripathi, 2023).

Tokens

The Blockchain & Web3 Observatory defines tokens as: *An instrument used for the management of non-native digital assets within a Blockchain platform. Tokens may be utilized as representations of other digital or physical goods, or of a right, such as the ownership of an asset or access to a service.* In simpler terms, a token is a digital unit that can be exchanged without intermediaries and can represent virtually anything: voting rights, a piece of art, a ticket, a subscription, or even the ownership of a house. Not everything is natively created in the form of a token. In fact, most of today's world still relies on paper-based processes or on intermediaries for guarantees. However, some companies have begun leveraging tokens, and the process of representing an asset or a right in the form of a token is referred to as **tokenization**.

Cryptography in blockchain

Cryptography plays a fundamental role in ensuring the security and integrity of blockchain technology. It is extensively employed in various aspects of blockchain to guarantee confidentiality, authenticity, and immutability of data and transactions. When a user initiates a transaction on the blockchain, cryptography is used to encrypt the transaction data, allowing only the intended recipient with the matching private key to decrypt and access the information, thus ensuring confidentiality and security. Digital signatures, created using cryptographic keys (private and public), are essential in blockchain transactions, verifying the authenticity of transactions and enabling traceability to the original sender.

Cryptography also plays a pivotal role in consensus protocols such as Proof of Work (PoW) and Proof of Stake (PoS), which help protect the blockchain network from malicious attacks and uphold its integrity through the use of cryptographic challenges and algorithms. Cryptographic hash functions are used to produce unique, fixed-size representations of block data, thereby ensuring the sequential connection between blocks and enabling the identification of any tampering or unauthorized changes. Cryptography further guarantees the safe management of private keys, which control access to digital assets and authorize transactions, thus preventing unauthorized use. Sensitive data, including personal and business-related information, is also protected through cryptographic encryption, which ensures confidentiality even when such data is stored on publicly accessible ledgers. In essence, cryptography underpins the entire blockchain framework, offering the essential mechanisms that allow the system to remain secure, transparent, and resistant to manipulation. This foundational security fosters trust among users, establishing blockchain as a dependable technology for diverse applications, from digital currencies and supply chains to identity management and beyond (Shi Dong, 2023).

P2P network technology

Since its introduction in 2009, Bitcoin has demonstrated remarkable stability in its operations, largely due to its implementation of peer-to-peer (P2P) network architecture. In contrast to conventional client-server systems, P2P structures offer numerous benefits such as increased privacy, decentralization, system resilience, efficient load distribution, and enhanced overall performance (Arun Sekar Rajasekaran, 2022). At its core, P2P technology is fundamentally based on the principle of decentralization. In the blockchain environment, this architecture enables the seamless global transfer of cryptocurrencies without the need for intermediaries or centralized servers. Utilizing a distributed network model, users who wish to validate transactions can operate a Bitcoin node. Blockchain functions as a decentralized ledger that records digital asset transactions over a P2P infrastructure. This setup consists of interconnected devices, each maintaining a full replica of the ledger. These nodes continually compare their records to maintain data consistency. This approach is notably different from traditional financial systems, where transactions are kept private and controlled solely by centralized institutions. Depending on their conceptual design, time of emergence, and network configuration, P2P systems can be categorized into three main types: first-generation hybrid networks, second-generation unstructured models, and third-generation structured P2P networks (Shi Dong, 2023).

Distributed ledger technology

There is a significant distinction between blockchain technology and traditional databases, mainly in terms of the fundamental operations they support. Conventional databases support four fundamental operations: insertion, deletion, modification, and data retrieval. On the other hand, blockchain systems are limited to only two functions: adding data and retrieving it. Importantly, blockchain does not allow for the alteration or removal of data once it has been stored. Traditional databases are generally divided into two categories: centralized and distributed databases. Distributed databases rely on high-speed communication networks to interconnect several geographically scattered storage units, thereby forming a single, logically integrated system. This structure enables the management of vast volumes of data and supports a higher level of simultaneous access (Shi Dong, 2023).

Asymmetric encryption and digital signature

Asymmetric encryption is based on the use of a paired set of keys—public and private—that possess distinct and complementary properties. These key pairs are generated systematically, with each pair consisting of one public key and its corresponding private key. A crucial aspect of this process is that the public key is openly available to anyone, while the private key remains securely protected and cannot be derived from the public key. Data encrypted using the public key can only be decrypted with the matching private key (Bharat Bhushan, 2021). Likewise, data encrypted with the private key can only be decrypted using the corresponding public key. To enable secure message transmission, the digital signature technique is employed (Shuyun Shi, 2020). The sender of the message first performs a hash operation on the message to produce a message digest. The resulting digital signature is then attached to the end of the message. The message is subsequently encrypted using the sender's private key. Upon receiving the message, the recipient decrypts it using the sender's public key, as shown in fig. 5. Then, the recipient applies the same hash function to the message to generate a digest, which is compared with the one provided in the signature. If the digests match, it confirms that the message has not been altered during transmission. On the other hand, blockchain technology is a form of distributed ledger technology (DLT). Although it shares certain similarities with distributed databases, it differs significantly in terms of data storage mechanisms and structural organization. The immutability of data recorded on the blockchain, combined with its decentralized architecture, guarantees a secure and transparent ledger for recording transactions. This ensures data integrity and trust among participants in the network.

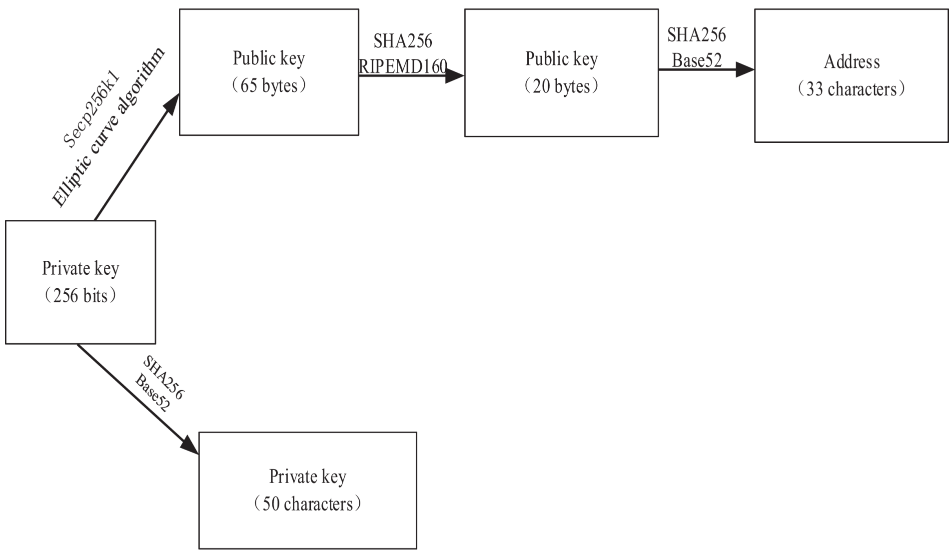

Figure 6 (Shi Dong, 2023).

The Elliptic Curve Cryptography (ECC)

Blockchain platforms utilize sophisticated algorithms to maintain both security and consensus across the network. Elliptic Curve Cryptography (ECC) ensures data protection by relying on a complex mathematical challenge known as the elliptic curve discrete logarithm problem, which makes the reverse derivation of private keys from public ones virtually infeasible. Despite what the name suggests, the elliptic curve cryptographic method does not directly involve an actual ellipse. Instead, its mathematical structure is similar to the integral formula used to calculate an ellipse's circumference.

The elliptic curve formula is typically expressed as:

$q = kp$

In this expression, k is a positive integer less than p, and p represents a fixed point on the curve that serves as the origin for scalar multiplication. While determining q from k and p is straightforward, the inverse, finding k given q and p, is computationally difficult and it would take a long time. This difficulty is what defines the elliptic curve discrete logarithm problem. Sharing q as the public key allows others to use it safely for encryption, whereas retaining k as the private key ensures that only the intended recipient can decrypt the communication (Umucu, 2022). Because of this, the elliptic curve discrete logarithm problem serves as a strong deterrent to unauthorized access, reinforcing the system's cryptographic security (Shi Dong, 2023).

Paxos algorithm

The Paxos algorithm helps achieve consensus in distributed systems, even when nodes fail, by allowing them to vote on proposals in phases until a majority agrees. The Paxos algorithm functions in a manner similar to parliamentary system, where proposals are introduced and collectively voted on by all participating members. The process is divided into two primary stages: the preparation phase and the submission phase. During the preparation stage, participants cast their votes on the proposed item. In the subsequent submission phase, the system determines whether the proposal will be officially accepted. In the commit stage, if the proposal secures a majority of affirmative votes from the nodes, the system issues an acknowledgment message, similar to a confirmation prompt on a webpage. When all nodes provide their confirmation, the proposal is accepted and deemed finalized. Conversely, if the required number of confirmations is not reached, a new proposal must be introduced to take its place, and the voting process restarts. Through this iterative mechanism, Paxos ensures consensus is reached even in environments where node failures may occur, thus providing a fault-tolerant solution for distributed systems (Shi Dong, 2023).

SHA256 algorithm

Lastly, SHA256, used in Bitcoin, is a hash function that produces fixed-length, irreversible, and random outputs, ensuring data integrity and forming the basis of the Proof of Work mechanism.

1.5 Distributed Shared Ledger

As blockchain technology begins to reshape how organizations manage, secure, and share data, one of its core innovations, the Distributed Shared Ledger (DSL), also referred to in some contexts as the Mutual Distributed Ledger (MDL), has emerged as a foundational component in this transformation. DSLs represent a decentralized data infrastructure that enables the secure recording, validation, and tracking of transactions across a network of independently operating computer systems. In contrast to traditional centralized databases managed by a single trusted third party, DSLs distribute transaction records across multiple nodes, each of which maintains a full or partial copy of the ledger. These ledgers operate on a peer-to-peer architecture, governed by a common protocol that ensures updates are synchronized, immutable, and tamper-resistant. In this context, DSLs significantly reduce reliance on centralized validation authorities by shifting trust to the underlying technology itself. As Mainelli and Smith explain (Smith, 2015), the integrity of the transaction record is maintained through cryptographic techniques and consensus algorithms, effectively displacing the traditional roles of third-party actors responsible for validation, safeguarding, and record preservation. This change is particularly relevant in enterprise environments where data integrity, auditability, and resilience are critical to operations. Although distributed ledgers were once regarded as too complex or insecure for practical deployment, these perceptions are rapidly evolving due to the rise of blockchain, a particularly robust implementation of DSL. As described by Hamilton (Hamilton, 2019), blockchain systems organize transactions into blocks, cryptographically link them, and distribute them across a decentralized network, enabling a self-governing, transparent, and permanent digital record. This feature is not only central to public cryptocurrencies like Bitcoin and Ethereum but is also increasingly being leveraged in private and permissioned enterprise systems. The peer-to-peer nature of DSLs allows all nodes in the network to participate equally in data verification, ensuring data consistency without centralized control. Moreover, DSLs can be tailored to organizational needs through a variety of architectural configurations. The InterChainZ project, as reported by Mainelli and Smith, outlined five practical configurations: (i) systems in which all nodes can write to the ledger; (ii) master node systems where only one node can make entries; (iii) supervisor node systems requiring co-signatures; (iv) majority-based systems requiring 51% consensus; and (v) collective validation systems demanding unanimous approval. These options offer enterprises flexibility in balancing governance, scalability, and operational efficiency. The relevance of DSLs to business applications extends far beyond cryptocurrency. As both Hamilton and Mainelli & Smith note, DSLs are being adopted across industries for functions such as supply chain transparency, digital identity verification, regulatory compliance, insurance, inter-organizational data sharing, and financial recordkeeping. From an enterprise perspective, Hamilton highlights that DSLs hold transformative potential for core accounting and treasury operations, particularly through the deployment of blockchain-based platforms like Corda (developed by R3) and Hyperledger Fabric. These platforms are designed for enterprise use, enabling secure, private, and scalable business networks. At the same time, DSLs provide a cost-effective and resilient alternative to centralized databases, especially in sectors where verification and auditability are critical. Consequently, DSL technology represents a paradigm shift in how enterprises manage transactional data and build trust across organizational boundaries. By decentralizing data governance and embedding cryptographic security at the protocol level, DSLs enhance transparency, reduce fraud risk, and increase operational efficiency across a wide range of applications. As the adoption of enterprise blockchain solutions continues to expand, DSLs are set to redefine the digital infrastructure of modern business, supporting not only financial transactions but also regulatory reporting, identity management, and collaborative ecosystems.

1.6 Consensus mechanism

A consensus algorithm serves as a foundational component within a blockchain network, enabling all participating nodes (or peers) to reach a unified agreement on the current state of the distributed ledger. Fundamentally, it operates as a protocol that facilitates collective decision-making regarding data integrity and ensures trust among entities that may not be inherently known or trusted. Blockchain networks typically implement an incentive-driven process for block creation, commonly referred to as block mining. Within this context, the consensus mechanism is a critical technology that determines which nodes are responsible for maintaining the ledger. It also guarantees the validation and synchronization of transaction data across the entire network. The consensus process generally comprises two primary phases: master selection and bookkeeping. Each round of this process is further segmented into four stages:

1. Master selection

2. Block generation

3. Data verification

4. Data uploading

Currently, a variety of consensus mechanisms are employed across different blockchain platforms. These include, but are not limited to: Proof of Work (PoW), Practical Byzantine Fault Tolerance (dBFT), Tangle (IOTA), Proof of Stake (PoS), Delegated Proof of Stake (DPoS) and Ripple Consensus Protocol. (Shi Dong, 2023)

It is crucial to recognize that the rapidly evolving nature of blockchain technology demands continuous attention to emerging vulnerabilities. Malicious actors are consistently enhancing their computational power, thereby presenting increasing security threats to blockchain infrastructures. The broad spectrum of consensus mechanisms highlights the innovative and adaptable character of the blockchain ecosystem, as these protocols are developed to address diverse use cases and system-specific requirements.

Notable Consensus Mechanisms

Proof of Stake (PoS)

Proof of Stake (PoS) is an alternative consensus mechanism wherein validators are selected based on the proportion of cryptocurrency they hold within the network, commonly referred to as their stake. This approach is widely regarded as more energy-efficient than Proof of Work (PoW), making it particularly well-suited for resource-constrained environments, such as those involving Internet of Things (IoT) devices. In a PoS-based system, participants must stake their coins in order to become eligible for validator selection. The likelihood of being chosen as a validator increases proportionally with the amount of cryptocurrency staked. To further encourage long-term holding and discourage speculative hoarding, the concept of coin days is introduced. Each unit of cryptocurrency accrues one coin day per calendar day it remains staked. For example, if a user holds 200 coins for 15 consecutive days, they accumulate 3,000 coin days (200*15 = 3,000). Upon the successful validation and addition of a new PoS block to the blockchain, the accumulated coin days are reset to zero, and the stakeholder is rewarded with interest. As an illustration, a yield of 0.05 coins per 365 coin days is offered. Therefore, an accumulation of 3,000 coin days would result in an approximate reward of 0.41 coins in interest (Shi Dong, 2023).

Delegated Proof of Stake (DPoS)

DPoS is a variation of the PoS mechanism, introducing a representative model where token holders vote for a limited number of delegates (also known as *witnesses* or *block producers*) who are then tasked with validating transactions and creating new blocks. Key characteristics of DPoS include:

1. **Voting:** Token holders elect delegates from a candidate pool, with voting power proportional to the number of tokens held.

2. **Block Production:** Delegates are assigned to produce blocks in a predefined order or a round-robin manner.

3. **Consensus:** Achieved when a supermajority of elected delegates approves a transaction for inclusion in the blockchain.

4. **Controlled Decentralization:** Although the system limits the number of block producers, token holders maintain the power to replace underperforming delegates through voting.

5. **Efficiency and Scalability:** DPoS offers high throughput and rapid block confirmation times.

6. **Security:** The model assumes that elected delegates act in the network's best interest. To deter malicious behavior, mechanisms such as vote slashing can be employed (Loss of reputation or

tokens). DPoS has been adopted by blockchain platforms such as Steem, BitShares, and EOS, striking a balance between decentralization, efficiency, and security (Shi Dong, 2023).

Proof of Work (PoW)

PoW is among the earliest and most foundational blockchain consensus mechanisms. It achieves consensus and secures the network through computational problem-solving in exchange for rewards. The process generally includes the following stages:

1. Nodes monitor and temporarily store data records, which are then verified for validity.

2. Nodes use computational power to test various random numbers.

3. Upon identifying a suitable number, the node constructs the block, beginning with the header and followed by transaction data.

4. The block is broadcast across the network. Once validated by other nodes, it is added to the blockchain, increasing the chain's height by one block.

PoW systems incentivize nodes to solve cryptographic puzzles (e.g., a SHA256 hash problem) that are difficult to compute but easy to verify. The objective is to find a hash value that is less than or equal to a defined target.

1.7 Smart Contracts

What Are Smart Contracts?

Despite their name, smart contracts are not legal documents, but rather programs that ensure the correct execution of agreed-upon conditions for all involved parties. Smart contracts are self-executing digital agreements embedded within a blockchain network, capable of automatically enforcing the terms of an agreement once predefined conditions are met. Originally conceptualized in the 1990s, smart contracts gained practical implementation with the advent of programmable blockchain platforms such as Ethereum. These contracts eliminate the need for trusted third parties by leveraging decentralized code execution validated by the network's nodes. As such, they enable secure, transparent, and rapid peer-to-peer transactions between parties, even in environments lacking mutual trust. Their primary advantages include reduced transaction risks, minimized administrative costs, improved process efficiency, and increased transparency. Smart contracts are designed using “if/when… then…” logic, allowing them to automate actions such as fund transfers, asset registration, and notifications based on real-time data. Their potential spans various sectors including healthcare, supply chain management, energy systems, and intellectual property enforcement. However, they also present technical challenges such as security vulnerabilities, difficulties in updating deployed code, and limitations in handling off-chain data. Despite these challenges, smart contracts represent a transformative technology that enhances automation, accountability, and trust in decentralized applications (Taherdoost, 2023).

1.8 Blockchain's applications

Figure 7 Mindmap abstraction of the different types of blockchain applications (Fran Casino, 2019)

Most authors commonly categorize blockchain applications into two main groups: **financial** and **non-financial**, as digital currencies make up a significant portion of current blockchain use cases. Another widespread approach is to classify them based on the **evolution of blockchain technology** across different generations, often referred to as versions 1.0, 2.0, and 3.0. An alternative method like the one of (Fran Casino, 2019) focuses on an **application-oriented classification**, which organizes blockchain applications by their practical use across various sectors, drawing insights from the analysis of existing studies and real-world implementations.

Financial Applications

Blockchain technology has increasingly become a transformative force in the financial sector, with its applications extending across a broad range of services including business operations, asset settlement, prediction markets, and economic transactions. It holds significant potential to enhance the sustainability of the global economy by delivering efficiency, transparency, and cost reduction to consumers, financial institutions, and regulatory frameworks. The global financial system is actively exploring blockchain-enabled solutions for the management and exchange of financial assets such as securities, fiat currencies, and derivative contracts. These innovations enable more efficient processing of capital market transactions, digital payments, loan management schemes, general banking services, financial auditing, and cryptocurrency exchanges. Leading financial institutions, such as Barclays, Goldman Sachs, Santander, Bank of America, and UniCredit, have initiated collaborative efforts to develop blockchain-based infrastructures, including platforms like R3 and the Global Payments Steering Group. Moreover, blockchain supports the development of decentralized prediction marketplace systems (PMS), such as Augur and Viacoin, which reward users for accurately forecasting real-world events. Platforms like BitShares offer tokenized digital assets and decentralized financial services, while projects such as Plasma and Ventures employ smart contracts to facilitate financial operations and establish new models of investment and trading. Additional financial applications include automated compliance, syndicated loans, asset rehypothecation, and over-the-counter markets. Ultimately, the continued integration of blockchain into the financial sector is expected to yield substantial operational cost savings and improve core functions such as centralized reporting, regulatory compliance, and interbank transactions (Fran Casino, 2019).

Integrity Verification

Integrity verification has emerged as one of the most promising fields of blockchain application, with solutions focusing on enhancing trust, transparency, and authenticity across various sectors. These blockchain-based systems enable the secure storage and verification of data related to the origin and lifecycle of products and services, with key application areas including provenance and anti-counterfeiting, insurance, and intellectual property (IP) management. In the domain of IP, blockchain allows creators to assert ownership and manage rights over digital content. Platforms such as Ascribe, Mediachain, and Monegraph offer functionalities ranging from ownership transfer and metadata management to monetization models for digital media. Factom and SilentNotary provide blockchain-based services for validating the existence of digital events, while KodakCoin facilitates image rights transactions via a blockchain-enabled licensing platform. Furthermore, blockchain technologies are increasingly used to combat counterfeiting, with solutions like Everledger and Blockverify enhancing supply chain transparency and product authentication. In the insurance sector, blockchain is being adopted to streamline processes including sales, underwriting, customer onboarding, claims processing, and reinsurance. Initiatives such as the Blockchain Insurance Industry Initiative (B3i) are actively developing industry-wide standards to improve operational efficiency. The integration of smart contracts further enables process automation, cost reduction, and faster service delivery, especially in health insurance where blockchain supports secure data storage, personalized coverage, and continuous risk assessment. These developments underscore blockchain's transformative potential in safeguarding digital integrity and modernizing legacy systems across critical industries (Fran Casino, 2019).

Public Sector and Governance Applications

Blockchain technology holds transformative potential for public governance by enabling secure, transparent, and decentralized service delivery. Traditionally, governments have been entrusted with maintaining citizen and enterprise records, but blockchain applications are now being explored to disintermediate such processes and enhance the integrity, accountability, and automation of public records management. Practical use cases span from legal document registration, taxation, voting, and identity management to more complex smart city infrastructures. Moreover, projects like the World Citizen initiative propose decentralized identification systems for stateless individuals or refugees. Blockchain can also support dispute resolution mechanisms through tamper-proof records, as seen in platforms like Mattereum, Stampery, and Pavilion.io. However, the implementation of blockchain in the public sector is not without challenges. (Evrim Tan, 2022) identify governance as a critical factor that determines the success or failure of blockchain adoption in public management. Their conceptual framework categorizes blockchain governance into three interrelated levels: micro (technical design choices such as infrastructure architecture and interoperability), meso (decision-making mechanisms and consensus protocols among users), and macro (institutional accountability and control structures). This multilayered approach recognizes that design choices at one level influence governance dynamics at others. Furthermore, blockchain governance requires a balance between centralized oversight and decentralized autonomy. Ultimately, blockchain serves not merely as a data storage solution, but as a governance technology that redefines trust and control in public administration. By encoding decision rules into smart contracts and enabling automated, transparent transactions, blockchain can decentralize authority while preserving institutional legitimacy.

Voting Systems

Blockchain-based voting solutions address long-standing issues in electoral processes such as transparency, security, and trust. Unlike centralized electronic voting systems, decentralized platforms like BitCongress and Liquid Democracy propose frameworks for distributed decision-making, enhancing voter confidence. Technologies such as Futarchy even link policy support to economic performance predictions. These innovations demonstrate the potential of blockchain to foster democratic legitimacy while ensuring compliance with legal frameworks (Fran Casino, 2019).

Internet of Things (IoT)

The convergence of blockchain and IoT technologies unlocks significant advantages, including secure data exchange, device identity management, and decentralized control. Blockchain enhances IoT scalability and mitigates issues such as security vulnerabilities and central points of failure. Applications range from automated supply chains and transportation systems to peer-to-peer (P2P) energy trading and smart grid management. Despite device-level constraints like limited computational power, lightweight blockchain architectures offer promising solutions .

Healthcare Management

Blockchain technology holds promise in revolutionizing healthcare through secure electronic health records (EHRs), fraud prevention, and clinical trial transparency. Smart contracts automate processes like insurance claims and informed consent, ensuring data integrity and patient privacy. Blockchain also supports interoperability between healthcare providers, enabling real-time access to medical data while minimizing risks of data breaches and unauthorized access (Fran Casino, 2019).

Privacy and Security

Blockchain enhances privacy and data protection through decentralized identity systems, immutable records, and encrypted transactions. Innovations such as Namecoin and Alexandria aim to provide censorship-resistant DNS and media libraries. Techniques like zero-knowledge proofs and mixing services further enhance transactional anonymity. These solutions contribute to safeguarding sensitive data in both public and private domains (Fran Casino, 2019).

Business and Industry

Blockchain introduces operational efficiencies across multiple industries by automating workflows and ensuring traceability. In business process management, smart contracts enable decentralized execution and reduce overhead costs. Blockchain applications improve e-commerce credibility, support human resource processes, and offer verifiable data management. As a result, businesses benefit from increased transparency, trust, and process optimization (Fran Casino, 2019).

Supply Chain Management

Blockchain technology increases supply chain transparency by recording each transaction in an immutable ledger. This facilitates real-time product tracking, counterfeit detection, and contract automation. Blockchain also enables better collaboration between logistics partners, improves food safety, enhances intellectual property protection, and supports secure customer data handling through encrypted analytics (Fran Casino, 2019). This thesis will dive deeper into this topic in the next chapter.

Energy Sector

In the energy domain, blockchain fosters decentralization and enhances peer-to-peer trading, especially for renewable energy sources. It supports energy communities, improves billing transparency, and facilitates the issuance of green energy certificates. Blockchain also contributes to electric vehicle energy management and aligns with global decarbonization goals, offering a secure and efficient digital infrastructure for modern energy systems (Fran Casino, 2019).

Education

Blockchain improves educational recordkeeping by securely storing certificates and learning outcomes. It enhances the management of reputational credentials, supports digital accreditation systems, and enables credit transfers under frameworks like the European Credit Transfer System (ECTS). These applications ensure data authenticity and help institutions manage student information transparently and efficiently (Fran Casino, 2019).

Data Management

Blockchain enables secure, decentralized data management across organizational boundaries. It ensures data authenticity and auditability, supporting metadata management, human resources, and cross-enterprise workflows. Applications include secure file storage, searchable data archives, and anonymized data sharing. These capabilities enhance trust and control in big data environments (Fran Casino, 2019) .

Green Certificates and Carbon Trading

Green certificates are tradable products that certify the quantity of renewable electricity generated by energy producers. These certificates can be exchanged among producers or traded with consumers. Within green power pricing mechanisms, green certificates allow producers to minimize additional costs associated with environmental protection and energy conservation. Additionally, government subsidies are often granted to companies based on the number of green certificates they possess. The integration of blockchain technology into green certificate systems introduces several advantages. It eliminates the need for centralized authorities to issue and audit certificates, thereby reducing administrative costs. The transparency and immutability provided by blockchain establish a trustworthy framework for renewable energy generation and trading. Moreover, the use of smart contracts can automate certification and transaction processes, helping to prevent errors and fraud. In parallel, carbon trading has emerged as an effective approach to managing and reducing carbon emissions. By assigning a monetary value to emission quotas or other carbon-related products, businesses are held to a higher level of financial accountability for their environmental impact. Large organizations can purchase voluntary emission reduction credits to offset emissions produced during their operations. This not only contributes to environmental responsibility but also enhances their public image and commitment to sustainability. Numerous blockchain-based carbon trading systems have already been implemented. Blockchain ensures the integrity of emission monitoring data and, through its decentralized nature, encourages broader participation from individuals and organizations in emission reduction efforts. As in the case of green certificate trading, blockchain strengthens trust and reliability in carbon markets through its inherent transparency and tamper-resistance (Wang, 2021).

1.9 Challenges and limitations of blockchain technology

Blockchain technology holds the promise of revolutionizing global transactions by enabling contracts to be digitally embedded within databases that are both transparent and resistant to tampering. This fundamental characteristic of blockchain reduces or removes the necessity for intermediaries such as banks, legal professionals, and other third parties. Despite its vast potential, blockchain still faces several obstacles and challenges that must be addressed to enable its broad implementation and adoption (Gautami Tripathi, 2023).

Cost of decentralization

Decentralization stands out as one of the most prominent features of blockchain technology. It promotes the involvement of each participant in the network—referred to as a node—in maintaining the ledger. In principle, this decentralized structure can alleviate performance issues typically caused by reliance on a central node, improve resilience against single points of failure, and eliminate the need for intermediary transaction fees. However, a significant portion of the existing literature tends to overlook the substantial energy and storage demands that accompany these advantages (Wang, 2021).

Energy cost

Distributed consensus plays a crucial role in ensuring the secure functioning of decentralized systems. Among the most prominent blockchain platforms employed in energy blockchain applications are Bitcoin and Ethereum, both of which utilize the Proof of Work (PoW) consensus mechanism. According to data presented by (Wang, 2021), Ethereum accounts for approximately 50% of the hundreds of scientific publications and practical implementations in the field, with 55% of these adopting PoW as their consensus method. PoW operates by requiring network nodes to solve computationally intensive cryptographic puzzles, a process known as “mining.” Nodes that engage in this process are referred to as miners, and they include the solution to these puzzles within their proposed blocks to demonstrate their computational effort. The first miner to submit a valid proof of work gains the right to generate the next block in the chain. However, this mechanism has drawn significant criticism due to its resource-intensive nature. The effort spent on solving mathematically arbitrary hash functions is often viewed as a substantial waste of energy. For instance, (Wang, 2021) estimates that Bitcoin’s annual electricity consumption ranges between 60 and 150 terawatt-hours (TWh). Furthermore, the energy consumption per transaction is comparable to that of an average German household over several weeks or even months. In response to these concerns, Ethereum has announced plans for the release of Ethereum 2.0, which will transition from PoW to a Proof of Stake (PoS) consensus model. Unlike PoW, PoS requires validators to commit monetary stakes rather than consume large quantities of energy, offering a more sustainable alternative for blockchain consensus (Wang, 2021).

Storage cost

Storage redundancy is a fundamental characteristic of all distributed systems, serving as a critical mechanism for enhancing resilience against system failures. In fully decentralized blockchain architectures, every participating node is required to maintain a complete copy of the blockchain ledger, which results in substantial data redundancy. For instance, in the case of Bitcoin, the total size of its blockchain data reached 285.06 GB as of June 2020 (Wang, 2021). In a network comprising 1,000 nodes, this would collectively amount to approximately 278.38 terabytes (TB) of storage consumption. As blockchain networks continue to grow and the volume of on-chain data increases, the resulting demand for storage becomes a significant challenge for the sustainability of blockchain-based systems. To address this issue, one proposed solution involves the use of lightweight nodes, which store only a portion of the blockchain data. However, this approach compromises the strong consistency typically required by consensus protocols, whereby all nodes are expected to synchronize data within a specified time frame. Since lightweight nodes retain only partial blockchain information, they depend on full nodes—which hold the complete dataset—for the verification of blocks. Although this strategy alleviates the burden on local storage and makes blockchain applications more practical, it introduces new dependencies on network resources. Despite its advantages, the deployment of lightweight nodes can expose the system to various security threats, including data availability attacks, brute-force attacks, and Denial-of-Service (DoS) attacks. Therefore, while this method enhances scalability and resource efficiency, it must be carefully implemented with adequate safeguards to mitigate potential vulnerabilities (Wang, 2021).

Slow mining for consensus

The contention of concurrent requests represents a primary cause of inconsistencies in consensus outcomes, as executing these requests in differing sequences across nodes can result in diverging system states. As previously noted, the process of solving cryptographic hash puzzles in Proof of Work (PoW) mining is highly time-consuming, with the expected duration for mining a single block being approximately 10 minutes (Wang, 2021).This intentional trade-off between time and computational effort is essential to control the rate of block generation and to reduce the likelihood of conflicts arising from the simultaneous submission of blocks. Although Proof of Stake (PoS) and Byzantine Fault Tolerant (BFT) consensus mechanisms do not require mining and thus offer better performance, PoW-based consensus remains the predominant approach in practical blockchain applications, particularly within the energy sector. Several reasons justify this preference:

- In PoS, the node responsible for block generation must deposit monetary stakes within each block it produces. If a block is subsequently deemed invalid, these stakes are forfeited. While this significantly reduces the time and energy expended during the mining phase compared to PoW, the introduction of monetary components can give rise to novel security risks.
- BFT consensus protocols achieve agreement through message exchange among nodes. However, such algorithms often rely on strong theoretical assumptions, including reliable communication links, fully connected networks, and partial synchrony. In real-world settings, the failure to uphold these assumptions can cause consensus processes to break down.

As a result, despite their higher energy consumption, PoW-based blockchain systems are still favored by system architects for their greater reliability in achieving distributed consensus under practical conditions (Wang, 2021).

Slow query

Another notable inefficiency of blockchain systems lies in their slow information retrieval capabilities. Specifically, the processing time for a single transaction on the Ethereum blockchain has been observed to be approximately 80 to 2,000 times slower than that of MySQL, a popular open-source database management system. This substantial performance gap is mainly due to the sequential, chained structure of blockchain data. In order to retrieve information, nodes must scan the entire sequence of blocks to identify and assemble the required records, resulting in a time-intensive querying process. As the blockchain continues to expand in size, this approach becomes increasingly inefficient. Considering that blockchain is frequently used not only for its security but also as a secure data storage solution, the issue of slow query performance represents a significant limitation that must not be underestimated (Wang, 2021).

Limited block size

Blockchain improves transaction processing efficiency by grouping client requests into fixed-size blocks, allowing multiple transactions to be handled in a single batch. While this batching mechanism theoretically increases throughput, the use of a fixed block size may pose significant limitations as the system scales. When the rate at which transactions are submitted exceeds the rate of block generation, unprocessed requests accumulate in a queue, leading to increased response latency for clients, server congestion, and, in more severe cases, potential denial of service. Additionally, as application scenarios become more complex, the average size of data records increases, making it necessary to split single records across multiple blocks. This fragmentation negatively impacts system throughput. For instance, in real-world conditions, the average Bitcoin transaction size has grown from 250 bytes to 600 bytes, while the actual throughput has dropped to around 2.8 transactions per second, a notable decline compared to the previously anticipated 7 transactions per second. Conversely, oversized blocks can also degrade performance. Research on the effect of block size on blockchain efficiency has demonstrated that while the confirmation time for a 1 MB block ranges from 2 to 20 seconds, the confirmation time for a 32 MB block increases significantly, ranging from 64 to 640 seconds. This increase in latency is due to the longer generation and propagation time required for larger blocks. Consequently, determining the optimal block size remains a critical challenge for the design and operation of blockchain systems (Wang, 2021).

Lack of scalability

Blockchain systems commonly suffer from scalability limitations, largely due to the nature of their underlying consensus mechanisms. Scalability refers to the capability of a system to efficiently handle increasing workloads as the number of clients or servers grows. Over the past few decades, the development of distributed consensus algorithms has been constrained by a well-known trilemma, referred to as the “DCS triangle”. This principle posits that a distributed consensus system can at best achieve two out of three properties—full decentralization, strong consistency, and global scalability—but not all three simultaneously. Consensus, which is at the heart of blockchain technology, represents a global synchronization problem that is inherently challenging to solve in a decentralized environment. Different consensus mechanisms—Proof of Work (PoW), Byzantine Fault Tolerance (BFT), and Proof of Stake (PoS)—each introduce distinct scalability challenges:

- PoW is characterized by low efficiency and high resource consumption, making it costly to operate and maintain large-scale blockchain networks.
- BFT algorithms depend on extensive communication among servers and between clients and servers, meaning that scaling the number of nodes results in a significant increase in the volume and complexity of message exchanges.
- PoS, while more energy-efficient, introduces monetary-based mechanisms which can lead to new security risks, thereby complicating the security management in large-scale systems.

These scalability concerns become even more critical in the context of Internet of Things (IoT) technologies, which play a pivotal role in next-generation energy infrastructures. The integration of IoT devices significantly increases the number of terminal nodes, thereby placing greater demands on the scalability of blockchain-based energy systems. However, the consensus mechanisms adopted by most current blockchain implementations are generally inadequate to satisfy the high scalability requirements of IoT-based applications. To build viable blockchain-powered energy systems, system designers must carefully select the most suitable consensus protocol and achieve a delicate balance among decentralization, consistency, and scalability—a non-trivial task given the constraints highlighted by the DCS triangle. As examples, platforms like Bitcoin and Ethereum struggle with scalability, while solutions such as the InterPlanetary File System (IPFS) relax consistency, BigchainDB relies on a centralized voting federation, and Omniledger attempts to find a more balanced approach (Wang, 2021).

Security Risks

Although blockchain is often praised for its anonymity, immutability, and resistance to single points of failure, it remains susceptible to a variety of cyberattacks. These include double spending, 51% attacks, selfish mining, withholding and balance attacks, as well as more sophisticated threats like eclipse attacks, bribery attacks, and quantum computing attacks. The energy sector's high level of centralization exacerbates these risks, especially 51% attacks, which become more feasible when a few dominant players control the majority of computational resources. Furthermore, privacy-preserving features may be undermined by side-channel analysis or transaction tracking, and the immutable nature of blockchain can complicate the removal of malicious content. While some of these threats may seem theoretical at present, their potential to disrupt energy systems, critical national infrastructure, renders them significant. Thus, the adoption of blockchain in energy systems must be accompanied by robust and adaptive security mechanisms to safeguard against these evolving risks (Wang, 2021).

CHAPTER 2 - Blockchain in Supply Chain Management

2.1 Understanding Supply Chain Management (SCM)

Supply Chain Management (SCM) is defined as "[. . .] the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" (John T. Mentzer, 2001). Since its inception over two decades ago (Houlihan, 1985), Supply Chain Management (SCM) has been primarily aimed at breaking down organizational silos and fostering both intra- and inter-organizational collaboration to enable a seamless, adaptable, and cost-effective movement of goods, with a strong emphasis on meeting end-customer needs. Yet, despite the widespread recognition of its benefits, the complete adoption of SCM practices in practical business contexts remains relatively rare (Abrahamsson, 2009). Obstacles to the adoption of SCM are diverse, encompassing technical barriers, such as difficulties with IT integration, as well as cultural issues, including the absence of trust between partners. SCM should be viewed not just as a collection of operational logistics techniques, but also as a managerial philosophy, an implementation system, and a sequence of interconnected business processes (John T. Mentzer, 2001). From a philosophical standpoint, SCM advocates for a comprehensive perspective that sees the entire supply chain as a unified and integrated system. It encourages synchronized collaboration within and across organizations to create unique value propositions for customers and to sustain long-term competitive advantage. As an implementation framework, SCM involves specific actions such as fostering integrated behaviour, sharing information, establishing joint risk and reward mechanisms, integrating processes, and building long-standing partnerships. From a process-driven viewpoint, SCM concentrates on the strategic management of structured flows, such as procurement, customer service, and order fulfilment, with an unwavering focus on the customer.

It is essential to differentiate between the mere existence of a supply chain, which naturally occurs during business operations, and the proactive management of that supply chain. Effective SCM necessitates that multiple entities within the network adopt a common strategic approach, known as Supply Chain Orientation (SCO), and engage in coordinated efforts to manage the movement of goods, services, information, and financial resources (John T. Mentzer, 2001).

Another key factor influencing successful SCM adoption is the active involvement of top management, whose support is consistently identified in academic studies and industry practice as crucial. However, a persistent challenge is the lack of sufficient engagement and understanding of SCM principles among senior executives, which obstructs its strategic assimilation. Thus, appreciating SCM extends beyond achieving logistical efficiencies; it involves a strategic dedication to customer satisfaction, inter-organizational trust, shared objectives, and adaptable systems that collectively contribute to building a unified and competitive supply chain.

2.2 Supply chain management evolution

The development of Supply Chain Management (SCM) illustrates a transition from static, efficiency-oriented models to systems that prioritize dynamism, resilience, and sustainability. In its traditional form, SCM primarily focused on minimizing costs, streamlining operations, and optimizing performance, often overlooking wider environmental and socio-political dimensions. Nevertheless, global crises such as the COVID-19 pandemic and the Russia-Ukraine war have exposed the fragility of linear, reductionist supply chains, prompting both scholars and industry leaders to reassess fundamental premises (WIELAND, 2021). A transformative viewpoint is gaining traction, one that conceptualizes supply chains as social–ecological systems that are intertwined with broader planetary, political-economic, and societal environments. Instead of being rigidly engineered for stability, contemporary supply chains are increasingly seen as adaptive entities that undergo cyclical phases of growth, collapse, reorganization, and renewal, aligning with principles drawn from panarchy theory. This emerging paradigm advocates for a more "fluid" approach to SCM, marked by experimentation, responsiveness, and the capacity to handle systemic shocks and transformations (WIELAND, 2021). Furthermore, recent trends stress the growing integration of Industry 4.0 technologies, including IoT, blockchain, artificial intelligence (AI), and big data analytics, which contribute to enhancing supply chain agility and transparency. These technologies not only drive operational advancements but also promote the implementation of Green Supply Chain Management (GSCM) and Circular Economy (CE) initiatives, which are increasingly recognized as essential for achieving sustainable supply chain performance (Chitra Lekha Karmaker, 2023). Specifically, the synergy among I4.0 technologies, GSCM practices, and CE principles has been demonstrated to influence the link between technological innovation and sustainability achievements. This marks a significant evolution, shifting SCM's role from a simple tool of operational optimization toward a strategic platform for resilience, adaptability, and environmental stewardship, especially within emerging economies where supply chains face persistent disruptions while striving for competitiveness and ecological responsibility (Chitra Lekha

Karmaker, 2023). As SCM progresses, it is increasingly informed by the Resource-Based View (RBV), which treats advanced technologies and sustainability-driven initiatives as key strategic assets that yield enduring competitive advantages. This theoretical integration reinforces the notion that supply chains must be perceived not merely as isolated technical systems but as intricate, evolving networks that can transform through coordinated innovation efforts and policy alignment (Chitra Lekha Karmaker, 2023) (WIELAND, 2021).

2.3 Areas of Improvement in SCM through Blockchain

The integration of Blockchain Technology (BCT) into Supply Chain Management (SCM) marks a major paradigm shift, offering solutions to persistent operational inefficiencies, information asymmetries, and trust issues among supply chain stakeholders. Blockchain's core attributes, decentralization, immutability, real-time data accessibility, cybersecurity, transparency, and traceability, position it as a transformative tool for strengthening various facets of supply chain performance. A key improvement blockchain introduces is enhanced information transparency and system-wide visibility. Traditional supply chains are often impeded by fragmented data management and isolated information systems, which restrict effective communication across different parties. Blockchain addresses these shortcomings by providing a distributed, tamper-resistant ledger where all participants have simultaneous access to consistent data. This fosters mutual trust and accountability, particularly in supply chains with multiple actors spread across different regions. As pointed out by ((Lucas Antonio Risso, 2023), blockchain integration facilitates real-time data updates and secure exchanges, enhancing process monitoring, decision-making, and overall network reliability and agility.

Traceability emerges as a critical driver for blockchain implementation within supply chains, especially when combined with IoT, RFID, and QR code technologies. Thanks to blockchain's immutable nature, traceability enables the monitoring of goods throughout the entire product lifecycle, thereby supporting quality assurance and inventory oversight. It reduces disputes, mitigates information asymmetries, and reinforces partner trust. Although challenges remain, such as concerns over confidentiality, difficulties with existing system integration, and complexity in tracing processed products, traceability remains beneficial for reverse logistics, remanufacturing efforts, and assigning ownership and environmental accountability. In highly complex supply chains in particular those in sectors like pharmaceuticals, food, and oil, the ability to track the provenance and movement of goods is essential for maintaining product quality, ensuring safety, and achieving compliance with regulatory standards. Blockchain's immutable records and sequential data linkage provide a robust mechanism for end-to-end traceability, enabling organizations to authenticate the journey of a product from its source to the final consumer. This capability not only supports recall management and fraud prevention but also strengthens consumer confidence and brand reputation.

Operational efficiency is also significantly improved through the deployment of smart contracts, which minimize manual processes, lower administrative expenses, and reduce human error while accelerating procurement, payment, and logistics coordination. This automation empowers supply chains to become more agile and responsive to shifting market demands. By monitoring operational metrics, smart contracts can help prevent damage during transit and bolster delivery reliability. They further streamline continuous process improvements, automate order replenishment and loan repayments, and initiate real-time financial transactions upon delivery verification. Smart contracts can also incorporate external data inputs, remove intermediaries, and help reconcile conflicting interests among stakeholders. Nevertheless, the effectiveness of smart contracts may be compromised by poorly written agreements and a lack of contextual awareness.

In the framework of sustainability and resilience, blockchain shows significant potential, especially when integrated with other Industry 4.0 technologies like the Internet of Things (IoT), big data analytics, and artificial intelligence. As emphasized by (Chitra Lekha Karmaker, 2023), these combined technologies advance the implementation of Green Supply Chain Management (GSCM) and Circular Economy (CE) practices, which are vital for enhancing both environmental and economic performance. For example, blockchain can verify the environmental compliance of suppliers or track product and material lifecycles to promote resource efficiency and minimize waste generation. These applications are particularly valuable in emerging markets, where supply chains often confront resource shortages, regulatory inconsistencies, and socio-economic vulnerabilities.

Blockchain also enhances supplier evaluation and performance monitoring. It enables real-time transaction processing, surpassing traditional alert-based systems. By digitizing paper-based documentation, it strengthens auditing capabilities and facilitates secure, efficient data sharing across international supply chains. When combined with sensor technologies, blockchain ensures data accuracy, supporting improved decision-making, digital twin development, and the creation of innovative business models. Real-time document sharing, particularly in customs operations and logistics, fosters greater agility and global cooperation. Blockchain's ability to record verified, tamper-proof data on supplier activities allows organizations to build transparent supplier performance scorecards, evaluating metrics such as delivery timeliness, ethical compliance, and environmental responsibility. This, in turn, promotes a culture of accountability and continuous improvement among supply chain partners and enables better-informed sourcing decisions.

Other key blockchain features that contribute to enhanced supply chain transparency and performance include:

Immutability

The immutability of blockchain data deters fraud, minimizes reconciliation needs, and ensures reliable credit histories. It enhances traceability, auditability, and the legitimacy of raw information. When paired with IoT, immutability facilitates information flow, recall processes, and social and environmental sustainability. However, it restricts data corrections and introduces concerns regarding data visibility and privacy.

Consensus Mechanism

Consensus mechanisms are fundamental to the trust model of blockchain. They validate data shared among unknown parties and ensure the consistency necessary for effective traceability. This validation process reduces opportunities for data manipulation and supports decentralized governance. Designing consensus protocols in harmony with supply chain structures is crucial for successful implementation.

Verifiability

Verifiability allows users to authenticate data and reduce audit times, such as checking sustainability records or verifying the origin of high-value or specialty items (e.g., organic, allergen-free products). It can also support monitoring supplier reputations, managing certifications, and ensuring transparency throughout the supply chain.

Peer-to-Peer Network

Peer-to-peer (P2P) configuration facilitates direct transactions without intermediaries, addressing issues of information asymmetry and promoting decentralized lending and asset exchanges. This model aligns with the principles of the sharing economy and becomes particularly powerful when integrated with IoT. However, regulatory oversight remains necessary to ensure compliance and security.

Permanent Availability

Blockchain ensures permanent availability of records, allowing for continuous and reliable access to transactional data. This persistent access supports supplier assessments, long-term audits, and uninterrupted operational analysis.

Chronological Chain (Timestamps)

Timestamps embedded within the blockchain offer chronological recordkeeping, supporting traceability, real-time auditing, and transparent documentation workflows. These time-based records aid in managing critical aspects such as lead times, deliveries, and product perishability.

Digital Signature

Though less frequently mentioned, digital signatures are recognized for preventing document forgery and offering decentralized trust. They help validate documents and transactions securely, reducing the dependency on centralized verification authorities.

Despite the clear benefits, the adoption of blockchain in SCM is not without challenges. As highlighted by Aslam et al. (2021), one of the primary barriers is the absence of a universally accepted implementation framework that guides decision-makers on how and when to deploy blockchain effectively. In addition, the high costs associated with infrastructure development, system integration, and personnel training often act as deterrents, especially for small- and medium-sized enterprises. Furthermore, concerns related to scalability, interoperability with existing systems, and data privacy must be adequately addressed before blockchain can be adopted at a large scale . In conclusion, blockchain offers a multifaceted enhancement to supply chain operations. It enables organizations to move from traditional, linear, and siloed models towards networked, transparent, and adaptive systems that align with modern-day requirements for efficiency, sustainability, and resilience. As the technology continues to evolve, further research and collaborative industry efforts will be essential to harness its full potential and establish best practices for widespread implementation in diverse supply chain contexts.

2.4 Blockchain Adoption in Enterprises: empirical studies

Given the limitations of traditional SCM and the potentialities of the BT outlined above, the following section explores two examples of how BCT can enhance SCM operations in real enterprises cases.

A study conducted by (Xiongfeng Pan, 2020) primarily sought to evaluate the effects of Blockchain Technology (BT) on the organizational capabilities (OCs) of enterprises. The study proposed that BT not only fosters mechanisms of trust and reduces transaction costs within firms but also reshapes incentive structures, thereby improving organizational synergy. Moreover, key attributes of BT, such as data integrity and decentralized processes, are seen as particularly supportive of supply chain management and operational optimization, exerting a significant impact on enterprise OCs. To empirically validate these theoretical propositions, the researchers carried out a quantitative analysis using data collected from 50 blockchain-listed companies in China. The results indicated that the total asset scale of a company is a major factor driving BT adoption, with larger enterprises showing a greater propensity to implement the technology. The measurement of organizational capabilities included indicators such as total asset turnover, current asset turnover, and sales expense ratios. The findings confirmed that the adoption of BT contributes positively to increasing asset turnover and decreasing sales-related expenses, thus enhancing overall organizational capabilities. Unlike earlier research primarily centered on business process modeling or technical design, this study offered empirical validation grounded in actual enterprise data. It illustrated how BT facilitates trust-building and collaboration within the supply chain, which in turn significantly strengthens enterprise OCs. However, two main limitations were acknowledged. Firstly, the importance of aligning BT investment with the firm's developmental stage was emphasized, with factors like managerial disposition, the structure of human capital, and the surrounding policy environment playing critical roles. Secondly, the study stressed the need for robust collaboration, information sharing, and resource exchange to fully leverage the advantages offered by BT. Future research is encouraged to further investigate these prerequisites and collaborative processes to fine-tune enterprise strategies for BT implementation.

Another investigation, conducted by (Ferdaws Ezzi, 2022), focused on assessing the impact of blockchain technology on Corporate Social Responsibility (CSR) performance within European firms. Building upon previous academic work, the study suggested that BT promotes trust mechanisms, lowers transaction costs, and enhances organizational coordination and social performance through its inherent features such as decentralization and data integrity. Empirical analysis was performed using data from 297 blockchain technology enterprises across Europe, examining how BT influences CSR performance across various stages of a firm's life cycle. The study's results demonstrated that several firm-specific characteristics, including total assets, workforce size, sales volume, and R&D intensity, play a significant role in influencing the probability of BT adoption. Among these factors, firm size, particularly asset volume, emerged as the most influential. Companies at the maturity stage of their life cycle exhibited the strongest positive correlation between BT adoption and improved CSR outcomes. This suggests that the stable context during the maturity phase provides optimal conditions for leveraging BT's potential to enhance CSR activities. CSR performance was assessed across eight key dimensions: human rights (HR), employment quality (EQ), community engagement (CO), diversity and inclusion (DIV), customer practices (CP), workplace health and safety (HS), environmental impact (EN), and workforce training and development (TD). The study revealed that BT has a positive influence on all these CSR components, particularly during the maturity stage of an enterprise's life cycle. Firms that actively integrate BT into their internal operations and external partnerships exhibit improved social responsibility practices, higher collaboration, and more robust stakeholder relationships. Furthermore, the paper emphasized that BT offers emerging solutions to social challenges by enhancing digital trust and enabling intelligent business operations. This not only increases an enterprise's core competitiveness but also supports sustainable strategic management by reducing environmental and social risks and improving operational efficiency. Two limitations of the study were acknowledged. First, the timing of BT adoption was found to be crucial, firms should implement BT during the maturity stage to maximize returns and CSR outcomes. Second, the decision to adopt BT is influenced by broader contextual factors beyond enterprise characteristics, such as leadership style, human capital composition, and the external policy environment. These considerations point to the need for future research to further explore governance mechanisms and the relationship between agency costs and CSR in BT-enabled enterprises.

In conclusion, blockchain is not merely a technological upgrade but a strategic enabler for SCM transformation. From improving traceability and trust to fostering sustainability and collaboration, its adoption, when properly aligned with organizational readiness, can yield significant gains. There will be a deeper analysis of the intention of adoption of the BT in the supply chain in the next chapter along with the literature review of the variables used in this thesis.

CHAPTER 3: Theoretical Foundation

This chapter provides a comprehensive explanation of the variables underpinning this study, supported by an in-depth review of the relevant literature.

3.1 ***Pressures Influencing Blockchain Adoption***

In an increasingly globalized economy characterized by intensified competition, technological innovation has become critical for organizational survival and growth ((Margarethe F. Wiersema, 2008); (Porter, 1980) (Michael Lustenberger, 2021). Scholars have attempted to explain the slow adoption of blockchain technology by highlighting internal organizational constraints, such as lack of awareness, technological immaturity, and cost-benefit uncertainties. However, these explanations often overlook the broader ecosystem in which organizations operate. In response to this gap, recent research has adopted the Technology–Organization–Environment (TOE) (R Depietro, 1990) to examine how various internal and external pressures influence blockchain adoption decisions. Environmental pressures, including regulatory uncertainty, competition intensity, stakeholder expectations, and partner influence, play a critical role in shaping organizational adoption behavior. At the same time, internal pressures such as organizational readiness, technological competence, and top management support significantly affect the capacity and willingness of firms to adopt blockchain (Michael Lustenberger, 2021). Additionally, commercial pressures driven by supply chain partners, clients, and industry consortia can compel organizations to engage with blockchain to remain competitive and interoperable within their ecosystems (Maciel M. Queiroz, 2019). Given the interplay of these diverse forces, this study seeks to explore how competitive pressure, trading partner pressure and top management support shape organizational decisions regarding blockchain, thereby contributing to a more comprehensive model of technology adoption in business environments. The study proceeds examining the relations between the intention of adoption and both perceived supply chain performance improvement and perceived supply chain transparency improvement.

3.2 Competitive pressure

As stated above, aside from the social behaviour and technology aspects, the external environment is also an important factor that needs to be considered in examining the adoption attitude towards blockchain technology. For example, the five-force model introduced by (Porter, 1980) indicates that external pressure is an important driver that pushes an enterprise to initiate the development of new innovative actions (Chien Hsing Wu, 2012). Generally, when facing significant changes in its environment, an organization will consider new things to adapt to those changes. The perception of an organization of the external environment will possibly affect its decision making, and consequently, the adoption of an innovation. Therefore, the external environment is an important factor that influences an organization to adopt innovative technology (e.g. customer-based and inter-organizational information systems). Competitive pressure refers to the degree of pressure that a company feels from competitors within the industry (Zhu and Kraemer, 2005). According to previous research like (Sachin S. Kamble, 2021) competitive pressure was found to be one of the most critical factors influencing the blockchain adoption. This finding found support in the literature form other studies (Chinyao Low, 2011) (Tiago Oliveira, 2010). Previous research also indicates that having more industry competition increases the possibility to innovate (Fariborz Damanpour, 1998), (Kevin K.Y. Kuan, 2001). In a highly competitive market, companies compete to maintain market status by using innovative technology. This implies that the higher the degree of competition an organization faces, the more positive willing it is to adopt innovative technology to increase its competitiveness. Moreover, as highlighted by (Chien Hsing Wu, 2012) literature indicates that competition pressure has been underlined as an important and positive external factor that influences an enterprise to adopt innovative ICT systems (G. Premkumar, 1995) ; (March L. To, 2006). Based on these concerns, this thesis considers the competitive pressure, which deals with the actions that the competitors of an enterprise make to gain business advantage, as an independent variable influencing block chain adoption, the results of the survey will be shown in the next chapter.

H1: Competitive pressure is positively related to the intention to adopt blockchain.

3.3 Trading partner pressure

Numerous empirical studies have demonstrated that pressure from trading partners serves as a significant facilitator for the adoption of technological innovations (Yu-Min Wang, 2010)**,** (Charalambos L. lacovou, 1995)**,** (Michael Lustenberger, 2021). Particularly, demands from influential trading partners, those who contribute substantially to a firm's sales or profit margins, are considered critical drivers in motivating organizations to adopt new technologies (Yu-Min Wang, 2010) . When dominant customers or suppliers embrace a specific innovation, firms may follow suit to demonstrate their alignment with partners' technological capabilities and to maintain their perceived legitimacy and competitiveness within the business relationship. In the broader context of information and communication technology (ICT), (Tuunainen, 2009) identified competitors and trading partners as the most influential external stakeholders affecting technology adoption decisions. This external pressure becomes particularly pronounced in smaller firms, which often possess limited market power and are more dependent on key business partners. According to (Charalambos L. lacovou, 1995), such dependence, especially when involving strategic partners, may compel organizations to adopt innovative solutions like blockchain technology to preserve critical alliances (Charalambos L. lacovou, 1995), further confirms that external trading partner influence, exerted through expectations or integration requirements, can substantially shape an organization's decision to implement blockchain, highlighting the broader role of inter-organizational dynamics in the adoption process (Michael Lustenberger, 2021).

H2: Trading partner pressure is positively related to the intention to adopt blockchain.

3.4 Top management support

Top management support is a significant element in the adoption of new technologies and has been found to be positively related to adoption (Grover, 1993) .Top management can provide a vision, support, and a commitment to create a positive environment for innovation (Acton, 2019). It also can send signals to various parts of the organizations about the importance of the innovation (Yu-Min Wang, 2010). Indeed, top management support has been identified as a key recurrent factor critical to the adoption of IT innovations by several studies like (Acton, 2019); (Rajiv Sabherwal, 2006) (Uday Kulkarni, 2017). In their study (Uday Kulkarni, 2017) defined top management support as "managerial beliefs about technological initiatives, participation in those initiatives, and the extent to which top management advocates technological advancement". High levels of top management support for a specific IT innovation ensure the long-term vision, commitment and optimal management of resources, creation of a favorable organizational climate, support in overcoming barriers and resistance to change (Yu-Min Wang, 2010) (Acton, 2019). In the context of blockchain adoption, the support of top management is crucial, as the implementation process often entails compliance with new regulatory requirements, navigating a high level of complexity, acquiring and integrating new resources, re-engineering both business-to-consumer and business-to-business transactions and information flows, as well as fostering the development of new skills and competencies (Acton, 2019). Accordingly, the following hypothesis was proposed:

H3: Top management support is positively related to the intention to adopt blockchain.

3.5 Intention of adoption

The 2018 study by Deloitte ((Linda Pawczuk, 2018)) revealed that there is great interest in blockchain, and firms are getting educated (40%) or creating a proof-of-concept (42.6%). Still, factors are holding back mass adoption and actual usage. The 2020 study by Deloitte (Pawczuk, 2020) showed a 13 % increase in blockchain adoption compared to the previous year (2019: 23%, 2020: 39%). However, the U.S. has still only seen a limited adoption, staying at 31%. Of the Chinese respondents, 59% had incorporated blockchain into production, highlighting a much higher adoption percentage (Milad Dehghani, 2022). With the variable speeds, blockchain adoption intention deserves further investigation. The previous research examines the opaque factors that support or inhibit a firm's intention to use blockchain technology, in my thesis I will focus on the influence the first three independent variables of my study (competitive pressure, trading partner pressure and top management support) have on the intention of adoption.

3.6 Supply chain performance perception

Supply chain performance plays a critical role in all types of organizations, and attaining such performance has been rendered more difficult by the increased complexity of operations in the digital age (Samuel Fosso Wamba, 2020). In the supply chain framework, blockchain is recognized as a disruptive technology (Tsan-Ming Choi, 2019) that can efficiently solve complex issues such as transparency and accountability (Biswas, 2017), security and resilience (Li Da Xu, 2018), trust, uncertainty, fraud prevention and the reduction of supply chain costs (Dominik Roeck, 2019), etc. Accordingly, integrating blockchain technology with supply chains is a trustworthy approach for supporting and remodeling the supply chain patterns and upgrading the level of service delivery (Samuel Fosso Wamba, 2020). Moreover, blockchain could be an appropriate mean of achieving supply chain sustainability (Sara Saberi, 2019)**.** While recent studies have emphasized blockchain benefits in the supply chain field, effective applications of this technology are still in their infancy, some recent studies like the one of (Samuel Fosso Wamba, 2020) focus on the value that blockchain can add to supply chain performance. In my thesis, I aimed to address the gap in the existing literature concerning the perceived improvements that blockchain adoption may offer to organizations' supply chain performance.

H4: The intention to adopt blockchain technology positively influences the perceived improvement in supply chain performance

3.7 Supply chain transparency perception

Blockchain applications play a key role also in ushering in more transparency in the processes, adequate data sharing and information between organizations (Xu, 2017), cooperation, as well as trust and efficiency (Kshetri, 2018), among others. (Christoph G. Schmidt, 2019) recognized the potential of blockchain to minimize transaction costs across the supply chains, reduce opportunistic behavior and increase transparency in the transactions. In my thesis, I adopted a different perspective by shifting the focus away from the concrete and well-documented benefits of blockchain, particularlyits ability to enhance transparency, and instead examined the perceived improvement in supply chain transparency following the potential adoption of blockchain technology. The emphasis was placed on the psychological perception of transparency rather than on its objectively proven outcomes

H5: The intention to adopt blockchain technology positively influences the perceived improvement in supply chain transparency.

SECTION 2: EMPIRICAL RESEARCH

CHAPTER 4– Empirical Study: Survey and Data Analysis

Theoretical background and development of conceptual model

4.1 Theoretical background

Hypothesis

This thesis based the empirical study on a survey relying on this hypothesis:

H1: Competitive pressure is positively related to the intention to adopt blockchain.

H2: Trading partner pressure is positively related to the intention to adopt blockchain.

H3: Top management support is positively related to the intention to adopt blockchain.

H4: The intention to adopt blockchain technology positively influences the perceived improvement in supply chain performance

H5: The intention to adopt blockchain technology positively influences the perceived improvement in supply chain transparency.

To test our hypotheses, the authors used an online survey (using prolific website) to collect data

Survey composition

The questions asked in the survey about trading partner pressure have been taken and modified from various studies indicated in each variable section:

Competitive pressure

Study of reference: Acceptance of enterprise blog for service industry Chien Hsing Wu Department of Information Management, National University of Kaohsiung, Kaohsiung, Taiwan, R.O.C. Shu-Chen Kao Department of Information Management, Kun Shan University, Tainan, Taiwan, R.O.C., and Hsin-Hui Lin Department of Information Management, National University of Kaohsiung, Kaohsiung, Taiwan, R.O.C

The questionnaire used a Likert seven-digit rating scale (from 1, strongly disagree to 7, strongly agree) with bi-polar descriptors in each question.

CP1: Not adopting blockchain while other enterprises do may result in a loss of customers.

CP2: Blockchain adoption is an important factor for gaining competitiveness when making strategic decisions.

CP3: Enterprises in my industry have recently begun adopting blockchain.

Trading partner pressure

Study of reference: Understanding the determinants of RFID adoption in the manufacturing industry Yu-Min Wang, Yi-Shun Wang , Yong-Fu Yang

The questionnaire used a Likert seven-digit rating scale (from 1, strongly disagree to 7, strongly agree) with bi-polar descriptors in each question.

PP1. The major trading partners of my company encourage the implementation of blockchain..

PP2. The major trading partners of my company recommend the implementation of blockchain.

PP3. Th The major trading partners of my company request the implementation of blockchain.

Top management support

Study of reference: Acceptance of enterprise blog for service industry Chien Hsing Wu Department of Information Management, National University of Kaohsiung, Kaohsiung, Taiwan, R.O.C. Shu-Chen Kao Department of Information Management, Kun Shan University, Tainan, Taiwan, R.O.C., and Hsin-Hui Lin Department of Information Management, National University of Kaohsiung, Kaohsiung, Taiwan, R.O.C

The questionnaire used a Likert seven-digit rating scale (from 1, strongly disagree to 7, strongly agree) with bi-polar descriptors in each question.

TS1. The top management of my company is likely to invest funds in blockchain.

TS2. The top management of my company is willing to take risks involved in adopting blockchain.

TS3. The top management of my company is interested in adopting blockchain applications to gain a competitive advantage.

TS4. The top management of my company considers the adoption of blockchain applications as strategically important.

Intention of adoption→ Behavioural Intention to Adopt Blockchain Technology (BI) –Adapted from Venkatesh et al. (2003)

Study of reference: High interest, low adoption. A mixed-method investigation into the factors influencing organisational adoption of blockchain technology * Milad Dehghania, Ryan William Kennedy b, Atefeh Mashatan b, Alexandra Rese c, Dionysios Karavidas a

BI1: Our organization intends to use blockchain technology regularly in the future.

BI2: Our organization plans to use blockchain technology or a similar system for transactions and processing requirements.

BI3: Our organization plans to implement blockchain technology within the next year.

Supply chain performance

Study of reference: Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation Samuel Fosso Wamba a, Maciel M. Queiroz b, Laura Trinchera c

Constructs were measured by a 7-point Likert scale (ranging from "strongly disagree" to "strongly agree").

SCPERF1 Blockchain reduces transaction costs in supply chain operations.

SCPERF2 Blockchain improves the level of service provided to customers.

SCPERF3 Blockchain increases the speed of supply chain operations.

SCPERF4 Blockchain enhances value creation in the supply chain.

Supply chain transparency

Study of reference: Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation * Samuel Fosso Wamba a, Maciel M. Queiroz b, Laura Trinchera c

Constructs were measured by a 7-point Likert scale (ranging from “strongly disagree” to “strongly agree”).

SCTRAN1 Blockchain improves the recording and transfer of asset quantities (e.g., pallets, -trailers, containers) as they move between supply chain nodes.

SCTRAN2 Blockchain enhances tracking of purchase orders, change orders, receipts, shipment notifications, and other trade-related documents.

SCTRAN3 Blockchain facilitates assigning or verifying certifications and properties of physical products (e.g., rganic or fair-trade status).

SCTRAN4 Blockchain strengthens the linkage of physical goods to serial numbers, barcodes, and digital tags (e.g., RFID).

SCTRAN5 Blockchain enhances the sharing of information related to manufacturing, assembly, delivery, and maintenance processes with suppliers and vendors.

4.2 ***development of conceptual model***

For validating the model, partial least squares (PLS)–structural equation modelling (SEM) has been preferred since it yields better results to analyze an exploratory study with no sample restriction (Akter et al., 2017; Hair et al., 2018). This PLS-SEM technique analyzes survey responses that were obtained from a structured set of questions (questionnaire).

This model studies the relations between the varialbes in an exploratory way, in particular it focuses on the impact the independet variablòes have on the dependent variables.

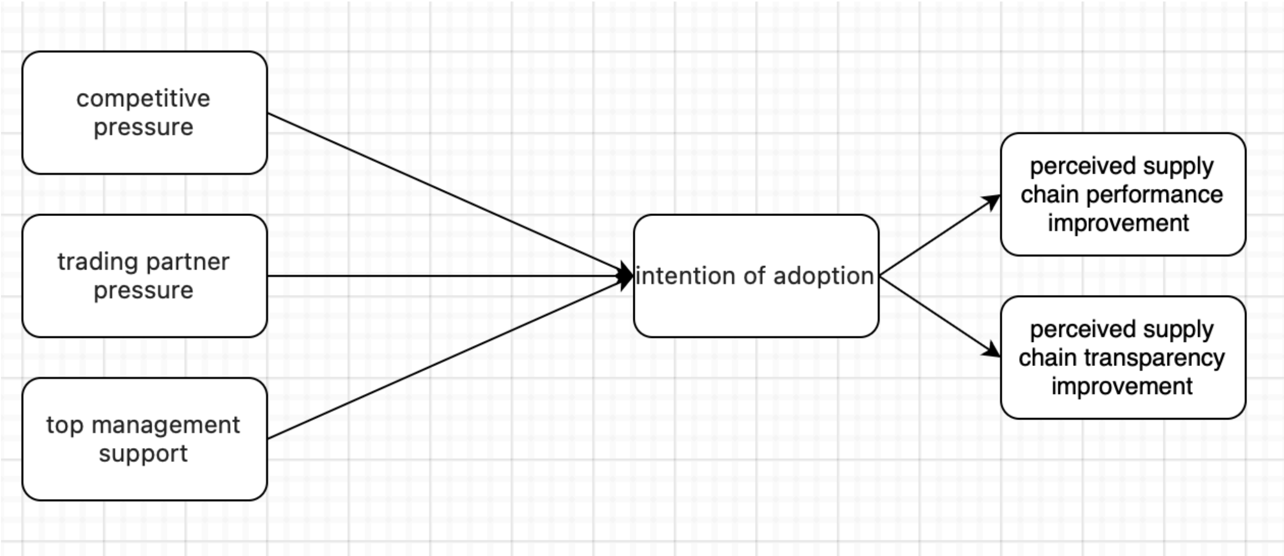

Figure 8 variables' relations

In particular here I study how the pressure variables (competitive pressure, trading partner pressure and top management support) have an impact on the intention of adoption, that will have an impact on perceived supply chain performance improvement and perceived supply chain transparency improvement.

We have quantified the responses using a 5-point Likert scale.

I received 232 responses. I scrutinized these responses and found that 23 responses were incomplete, which I disregarded. We began our PLS-SEM analysis with 208 usable respondents. The detailed information of the respondents is provided in Table 1.

Table 1 detailed information of the respondents

Particulars	**Category**	**Frequency**	**Percentage**
Gender	Male	102	49,04%
	Female	106	50,96%
Education	High school or below	31	14,90%
	Bachelor's degree	104	50%
	Master's degree	59	28,37%
	Doctorate degree	14	6,73%
Job tenure	Less than 1 year	12	5,77%

	7-10 years	24	11,54%
	4-6 years	60	28,85%
	1-3 years	57	27,40%
	More than 10 years	55	26,44%
Job position	Entry-level/Junior Staff	36	17,31%
	Mid-level/Supervisor	88	42,31%
	Executive/C-Level	23	11,06%
	Senior Manager/ Department Head	61	29,33%
Geography	Europe	103	49,52%
	North America	29	13,94%
	South America	51	24,52%
	Asia	10	4,81%
	Australia	15	7,21%
Industry	Manufacturing	19	9,13%
	Technology	58	27,88%
	Healthcare	20	9,62%
	Finance	31	14,90%
	Retail	12	5,77%
	Education	19	9,13%
	Agriculture	3	1,44%
	Other	46	22,12%

4.3 ***Regression***

Mean, STDEV, T-Values, P-Values

Table 2 Mean, STDEV, T-Values, P-Values

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|0/STDEV|)	P Values
COMPPRES → INT	**0,102**	**0,106**	**0,060**	**1,709**	**0,088**
INT →SCP	**0,698**	**0,701**	**0,039**	**18,017**	**0,000**
INT →SCT	**0,639**	**0.643**	**0,048**	**13.289**	**0,000**
TMPRESS →INT	**0,401**	**0,403**	**0,100**	**4,010**	**0,000**
TRADPARTPRES → INT	**0,420**	**0,416**	**0,091**	**4,620**	**0,000**

Following the theoretical model proposed by Chatterjee (Sheshadri Chatterjee, 2021) the results of my PLS-SEM model (table 2) indicate that:

The relationship between competitive pressure and the intention to adopt blockchain technology is not statistically significant ($p = 0.088 > 0.05$), with a path coefficient of 0.102 and a confidence interval including zero ([-0.007; 0.220]), suggesting that competitive pressure alone does not drive the intention to adopt in this context. The relations between intention of adoption and supply chain performance and transparency perception are significative, since they have a p-value lower than 0.05.

On the other hand, the relationships between intention to adopt and both perceived supply chain performance (SCP) and perceived supply chain transparency (SCT) are highly significant ($p < 0.001$), with strong path coefficients of 0.698 and 0.639, respectively. These results support the idea that the intention to adopt blockchain positively impacts perceptions of operational improvement.

Furthermore, the relationship between top management support and intention to adopt is statistically significant ($p < 0.001$), with a moderate positive coefficient (0.401). Similarly, the pressure from trading partners shows a significant and strong effect on intention ($p < 0.001$, coefficient = 0.420).

Both relationships suggest that internal support and external collaboration pressures are key drivers in the decision to adopt blockchain technologies.

All significant relationships are further confirmed by their confidence intervals not including zero, indicating robustness of the model results (table 2,3)

Table 3 Confidence Intervals

	Original Sample (O)	Sample Mean (M)	2.5%	97.5%
COMPPRES → INT	**0,102**	**0,106**	**-0,007**	**0,220**
INT →SCP	**0,698**	**0,701**	**0,623|**	**0,763**
INT →SCT	**0,639**	**0.643**	**0,544**	**0,729**
TMPRESS →INT	**0,401**	**0,403**	**0,203**	**0,584**
TRADPARTPRES → INT	**0,420**	**0,416**	**0,242**	**0,587**

Table 4 Confidence Intervals Bias Corrected

	Original Sample (O)	Sample Mean (M)	Bias	2.5%	97.5%
COMPPRES → INT	**0,102**	**0,106**	**0,004**	**-0,018**	**0,213**
INT →SCP	**0,698**	**0,701**	**0,003**	**0,609**	**0,757**
INT →SCT	**0,639**	**0.643**	**0,004**	**0,524**	**0,719**
TMPRESS →INT	**0,401**	**0,403**	**0,002**	**0,175**	**0,575**
TRADPARTPRES → INT	**0,420**	**0,416**	**-0,004**	**0,244**	**0,592**

4.4 ***Quality Criteria***

The structural model in fig 9 was assessed to examine the relationships between the constructs and evaluate the explanatory power of the model through R^2 (coefficient of determination) and f^2 (effect size) values.

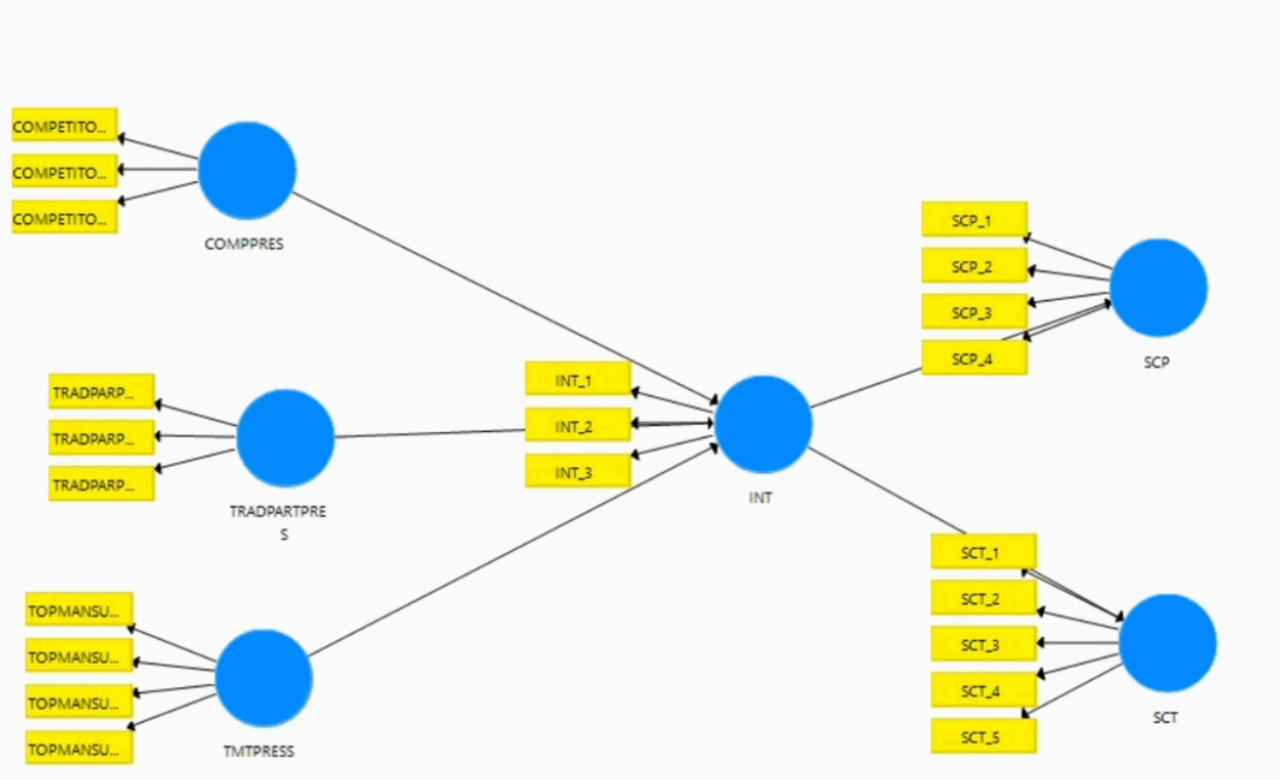

Figure 9 structural model

As shown in the structural model diagram, paths were hypothesized between the three external drivers (competitive pressure, trading partner pressure, top management support) and the intention to adopt blockchain, which in turn was expected to influence the perceived improvements in supply chain transparency and performance.

“Quality Criteria” in SmartPLS are fundamental for assessing whether the PLS-SEM model is statistically valid and reliable.

Considering that the R^2 indicates the proportion of variance in each endogenous construct explained by its predictors value, the higher the R^2 value, the more predictive the model is (with values above 0.70 considered excellent, and those above 0.40 considered good).

Table 5 R square and R square adjusted values

	R Square	R Square Adjusted
INT	0,764	0,76
SCP	0,487	0,485
SCT	0,408	0,405

As indicated by the table 5 which reports the data collected in the survey: INT (0.764): The model explains 76.4% of the variance in the intention to adopt, which represents an excellent level of explanatory power.

SCP (0.487): The model explains 48.7% of the perceived improvement in supply chain performance, which is considered a good level.

SCT (0.408): The model explains 40.8% of the perceived transparency in the supply chain, which is acceptable.

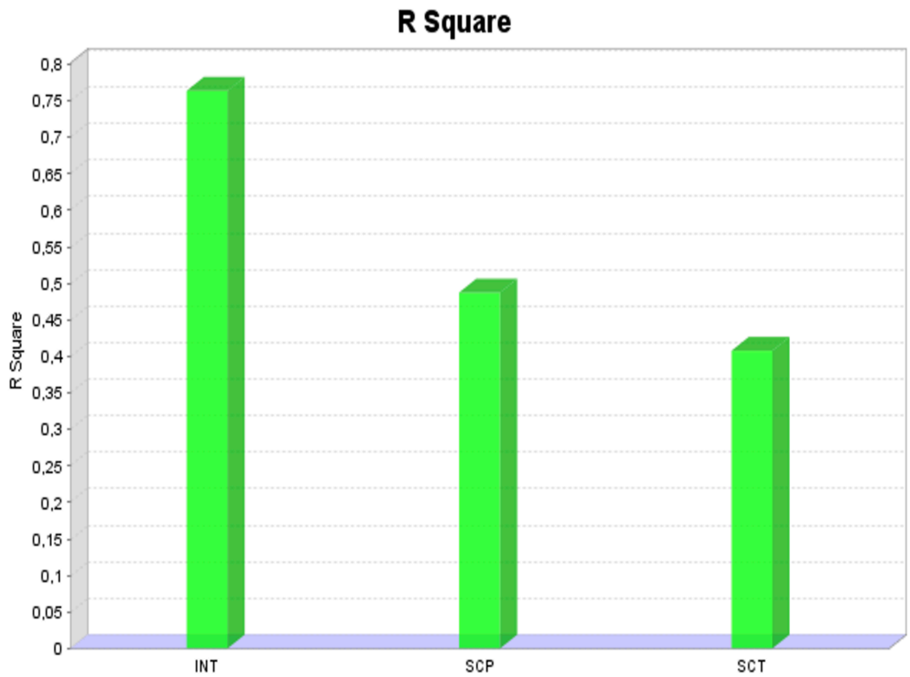

Figure 100 R square

Since R^2 can increase simply by adding more predictors, regardless of their actual contribution, a complementary metric has been used: the Adjusted R^2.

The Adjusted R^2 corrects for the number of predictors in the model and provides a more conservative and reliable estimate of the explained variance, particularly in models with multiple independent variables. It only increases if the added variables meaningfully improve the model's explanatory power.

The results in fig 11 show that: 76.4% of the variance in the intention to adopt blockchain (INT) is explained by competitive pressure, trading partner pressure, and top management support. The adjusted R^2 (0.760) confirms the stability of this result, indicating that the model is not overfitting. For supply chain performance (SCP) and transparency (SCT), the adjusted R^2 values (0.485 and 0.405 respectively) are only slightly lower than the original R^2 values, suggesting that the model remains robust and well specified, even with a moderate number of predictors. Thus, the Adjusted R^2 values confirm the reliability and parsimony of the model, ensuring that the explained variance is not artificially inflated by unnecessary predictors.

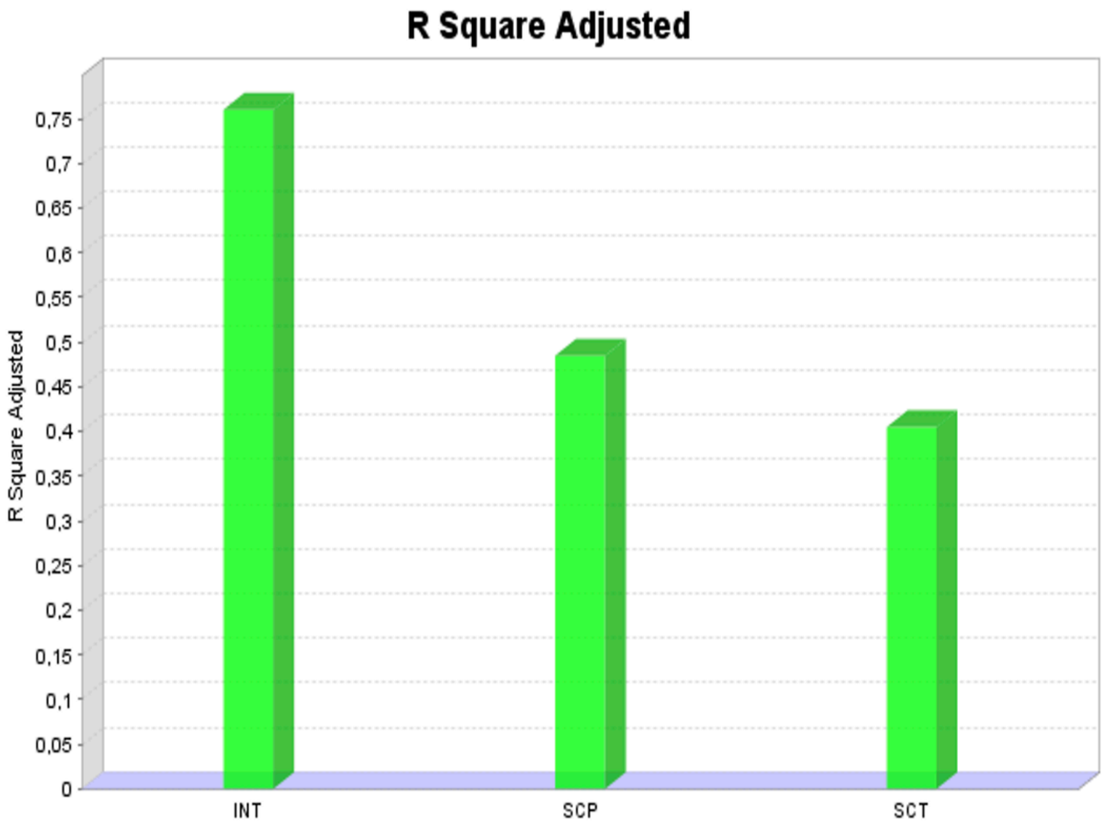

Figure 11 R square adjusted

4.5 F Square (f²) – Individual Effect Size (Contribution):

Table 6 F square results

	COMPPRES	INT	SCP	SCT	TMTPRESS	TRADPARTPRES
COMPPRES		0,016				
INT			0,951	0,689		
SCP						
SCT						
TMTPRESS		0,166				
TRADPARTPRES		0,177				

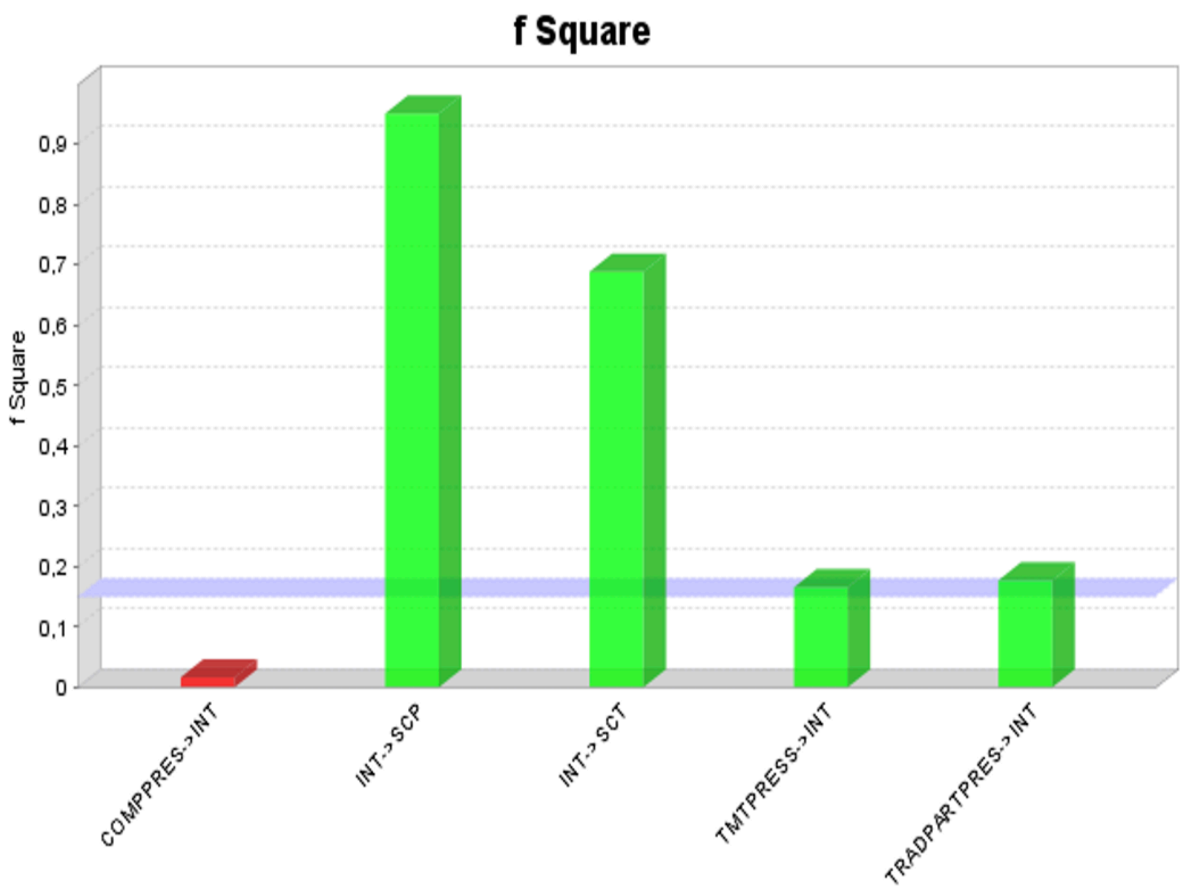

Figure 12 F square results

The f² statistic quantifies the individual contribution of each predictor to the explained variance of the dependent construct. Therefore, it shows how much an independent variable contributes to explaining the variance of a dependent variable. According to (Cohen, 1988) f² values can be interpreted as follows: Small = 0.02, Medium = 0.15, Large = 0.35

Looking at the survey's results in table 6 these values confirm that both top management support and trading partner pressure have moderate individual impacts on the intention to adopt blockchain, whereas competitive pressure has a marginal effect. Moreover, intention to adopt has a strong effect on both supply chain performance and transparency perceptions.

COMPPRES → INT: Negligible effect

INT → SCP (0.016): Very small effect

TMTRESS → INT (0.166): Moderate effect

TRADPARTRES → INT (0.177): Moderate effect

*4.6 **Cronbach's Alpha, Composite Reliability (CR) and Average Variance Extracted (AVE)***

Table 7 Cronbach's Alpha, Composite Reliability (CR) and Average Variance Extracted (AVE)

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
COMPPRES	0,799	0,879	0,709
INT	0,953	0,970	0,914
SCP	0,907	0,934	0,781
SCT	0,939	0,953	0,803
TMTPRESS	0,960	0,971	0,892
TRADPARTPRES	0,944	0,964	0,899

To ensure the robustness of the measurement model, the constructs were evaluated for internal consistency reliability and convergent validity using three key indicators: Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE).

Cronbach's Alpha is a traditional measure of internal consistency reliability, indicating how well the items of a construct correlate with one another. Values above 0.70 are considered acceptable, while values above 0.90 reflect excellent reliability. As shown in the table 7, all constructs exceed the 0.70 threshold, confirming that the items consistently measure their respective latent variables.

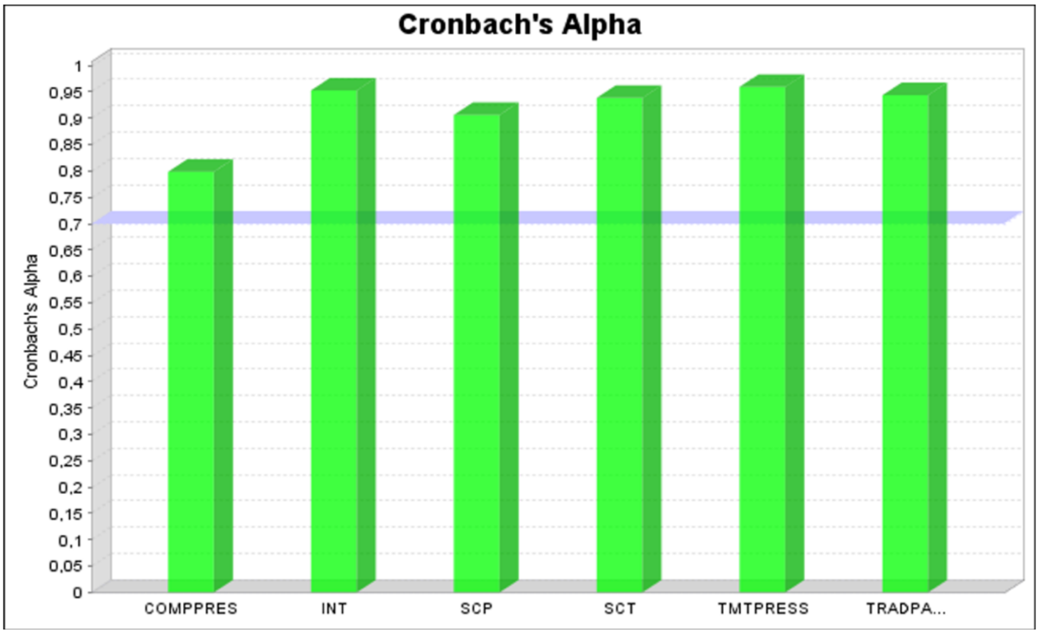

Figure 13 Cronbach's Alpha

Composite Reliability accounts for the outer loadings of each indicator and is considered more precise than Cronbach's Alpha in the context of PLS-SEM. A CR value above 0.70 is considered acceptable; values between 0.80–0.95 indicate high to very high internal consistency. These results confirm that all constructs possess strong composite internal reliability.

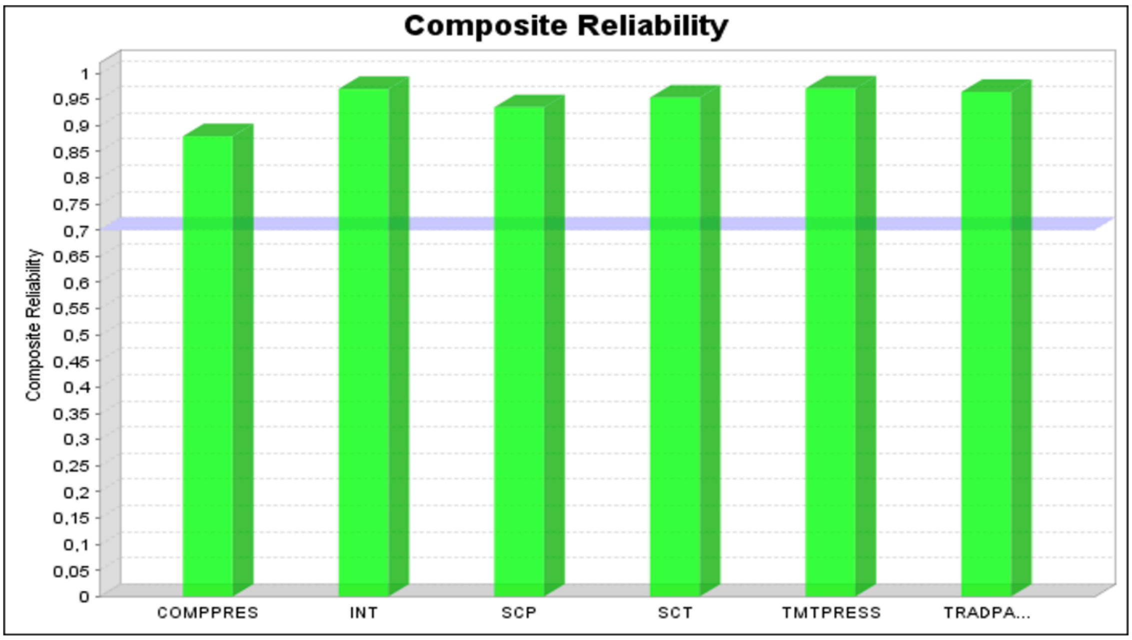

Figure 14 Composite Reliability

AVE (Average Variance Extracted) AVE measures convergent validity, indicating how well the observed indicators represent the underlying construct. In other words, it measures the amount of variance captured by the construct relative to the variance due to measurement error. An AVE of 0.50 or higher suggests sufficient convergent validity, meaning the construct explains more than half of the variance of its indicators. All constructs exceed the minimum AVE threshold, confirming that the indicators are well correlated with their corresponding constructs.

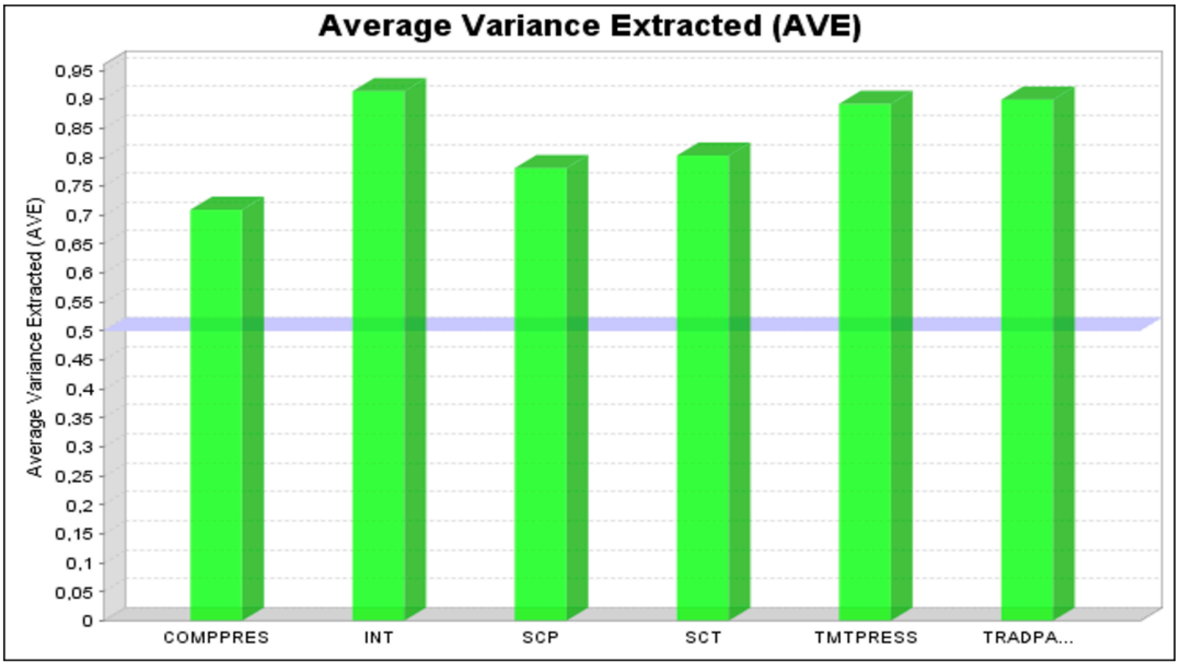

Figure 15 AVE (Average Variance Extracted)

*4.7 **Discriminant Validity – Fornell-Larcker Criterion***

Table 8 Fornell-Larcker Criterion

	COMPPRES	INT	SCP	SCT	TMTPRESS	TRADPARTPRES
COMPPRES	0,842					
INT	0,730	0,956				
SCP	0.653	0,698	0,884			
SCT	0,651	0,639	0,769	0,896		
TMTPRESS	0,761	0,837	0,606	0,613	0,945	
TRADPARTPRES	0,768	0,841	0,654	0,652	0,854	0,948

Table 9 Cross Loadings

	COMPPRES	INT	SCP	SCT	TMTPRESS	TRADPARTPRES
COMPETITOR 2	0,903	0,644	0,647	0,646	0,668	0,682
COMPETITOR 3	0,845	0,707	0,509	0,527	0,732	0,738
INT_1	0,726	0,959	0,658	0,618	0,815	0,801
INT_2	0,686	0,958	0,698	0,613	0,815	0,793
INT_3	0,681	0,950	0,645	0,601	0,779	0,819
SCP_ 1	0,477	0,475	0,810	0,611	0,416	0,458
SCP_ 2	0,563	0,648	0,890	0,685	0,558	0,607
SCP _3	0,635	0,643	0,911	0,698	0,563	0,597
SCP_ 4	0,617	0,674	0,920	0,718	0,582	0,628
SCT_ 1	0,597	0,558	0,708	0,894	0,595	0,612
SCT_ 2	0,576	0,569	0,688	0,897	0,527	0,582
SCT_ 3	0,567	0,553	0,658	0,892	0,510	0,552
SCT_ 4	0,560	0,537	0,677	0,900	0,529	0,612
SCT_ 5	0,613	0,634	0,712	0,897	0,582	0,612
TOPMANSUP_1	0,707	0,760	0,509	0,516	0,913	0,737
TOPMANSUP_2	0,695	0,783	0,565	0,589	0,944	0,804
TOPMANSUP_3	0,725	0,801	0,602	0,591	0,964	0,825
TOPMANSUP_4	0,746	0,818	0,610	0,619	0,958	0,858
TRADPARPRESS_1	0,705	0,785	0,620	0,626	0,795	0,945
TRADPARPRESS_2	0,765	0,826	0,662	0,620	0,840	0,958
TRADPARPRESS_3	0,714	0,780	0,577	0,609	0,794	0,942
COMPETITOR 1	0,774	0,441	0,491	0,455	0,472	0,470

Table 10 Heterotrait-Monotrait Ratio (HTMT)

	COMPPRES	INT	SCP	SCT	TMTPRESS	TRADPARTPRES
COMPPRES						
INT	0,811					
SCP	0,759	0,742				
SCT	0,741	0,673	0,831			
TMTPRESS	0,845	0,875	0,642	0,644		
TRADPARTPRES	0,859	0,886	0,699	0,692	0,896	

To verify discriminant validity, three approaches were used: the Fornell-Larcker criterion (table 8) , cross loadings (table 9), and the Heterotrait-Monotrait Ratio (HTMT) (table 10), in accordance with the procedures followed by Chatterjee et al. (2021).

The Fornell-Larcker results show that for each construct, the square root of the AVE exceeds its correlations with other constructs, confirming discriminant validity. This criterion assesses whether the constructs are sufficiently distinct from one another. Each value on the diagonal (in bold, e.g., 0.842 for COMPPRES) must be greater than any other value in the same row and column. In this model, all diagonal values are higher than the corresponding off-diagonal values, thus confirming discriminant validity.

Cross-loading analysis further supports this, as each item has its highest loading on its assigned construct compared to others.

Lastly, all HTMT values fall below the threshold of 0.90, indicating sufficient discriminant validity even under a more stringent criterion.

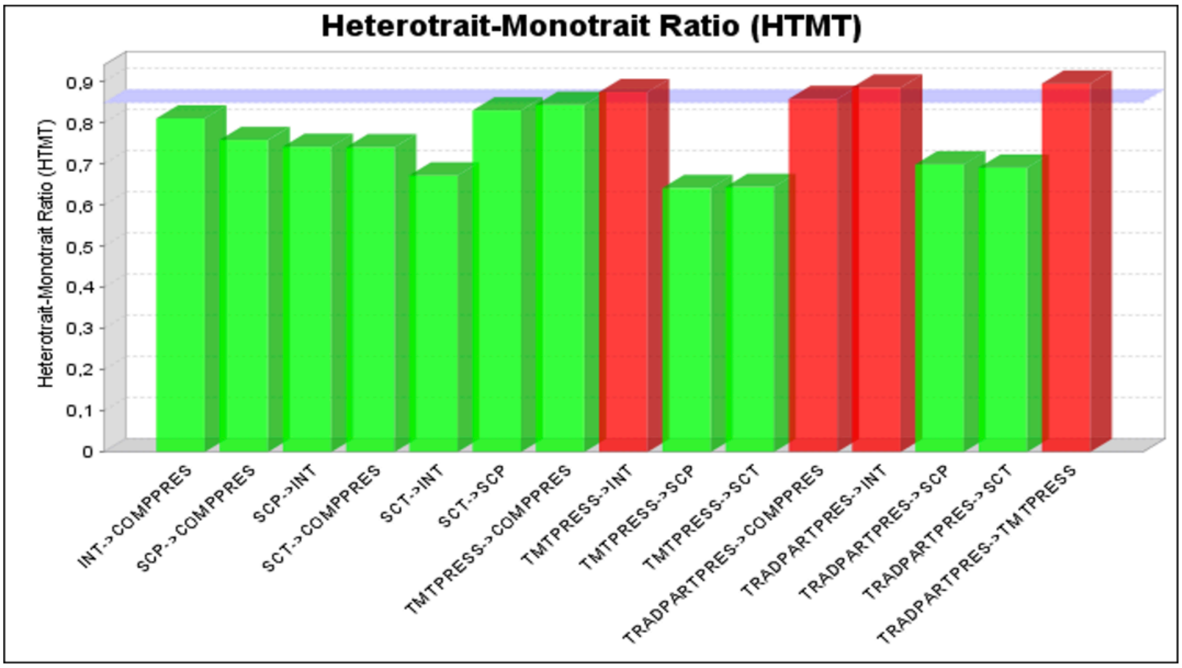

Figure 16 Heterotrait-Monotrait Ratio (HTMT)

Therefore, all constructs are shown to be statistically distinct from one another, validating the measurement model.

CHAPTER 5 - Discussion and Conclusions

5.1 Results' discussion

This thesis has examined the role of various pressures, in particular competitive e pressure, trading partner pressure and top management support on the adoption of Blockchain Technology (BCT). The analysis focused also on the perceived improvement in supply chain transparency and performance rather than on the objectively proven technological benefits. The study aimed to address a gap in the literature by exploring how psychological and organizational perceptions influence the intention to adopt blockchain at an international level.

Drawing upon the Technology–Organization–Environment (TOE) framework, the research proposed a model that integrates technological, organizational, and environmental factors with a specific emphasis on perceived transparency, trust, interoperability, top management support, and trading partner pressure. This model was empirically tested using data collected through a structured questionnaire distributed to a relevant sample of professionals and organizations. The analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM), which enabled the evaluation of the latent constructs and the strength and direction of their interrelations.

The empirical findings provide several noteworthy insights. Firstly, the results confirm that perceived transparency plays a central role in influencing the intention to adopt blockchain in the supply chain. This perception is not merely a function of technological performance but also of how individuals and organizations anticipate blockchain to enhance visibility, accountability, and traceability across the network. Importantly, trust emerged as a significant mediating variable, demonstrating that the impact of perceived transparency on adoption intention is reinforced when organizations perceive blockchain as a trustworthy enabler.

Secondly, top management support was found to be a strong and statistically significant predictor of adoption intention. This reinforces the notion that strategic commitment at the executive level is essential for the successful integration of disruptive technologies. Leadership not only determines the allocation of financial and human resources but also shapes the organizational culture toward innovation and change readiness.

Conversely, trading partner pressure, although often cited in the literature as a potential external driver of adoption, did not exhibit a strong influence in this study. This finding suggests that, at least within the observed sample, the decision to adopt blockchain is driven more by internal strategic vision than by coercive or normative pressures from external stakeholders.

From a methodological standpoint, the results demonstrate satisfactory levels of reliability and validity across constructs. Cronbach's alpha and Composite Reliability (CR) values exceeded accepted thresholds, and convergent and discriminant validity were confirmed through AVE and Fornell–Larcker criteria. The R^2 values for the endogenous constructs, particularly for trust and adoption intention, were robust, indicating that the model explains a significant portion of the variance.

Furthermore, the study's exploration of effect sizes (f^2) and predictive relevance (Q^2) adds depth to the analysis, highlighting which variables exert the most meaningful influence on the system and providing practical guidance for both academics and practitioners.

5.2 Theoretical Contributions

This thesis offers several important theoretical contributions to the growing literature on blockchain technology adoption in the context of supply chain management (SCM). Drawing on the Technology–Organization–Environment (TOE) framework, this study proposes and empirically tests an integrated model that combines established organizational and environmental drivers with a focus on perceived improvements, particularly in transparency and performance, as a result of blockchain adoption. The originality of this research lies in its emphasis on perceptions rather than objective or post-adoption outcomes, contributing a new angle to existing adoption theories.

1. Enriching the TOE Framework with Perceptual Outcome Variables

The TOE framework is widely used in information systems research to understand how organizations adopt and implement new technologies. However, prior applications of the framework have often focused on the antecedents of adoption, while offering limited attention to the expected outcomes from the organization's point of view. This thesis addresses this gap by incorporating two post-adoption perceptual constructs, Perceived Supply Chain Transparency Improvement (SCT) and Perceived Supply Chain Performance Improvement (SCP), as dependent variables in the structural model. By positioning these two constructs as expected benefits that follow from the intention to adopt blockchain, the study enhances the TOE model with a forward-looking and perception-based logic. This allows for a more realistic understanding of how expectations of improvement influence strategic decisions within organizations, especially under conditions of technological uncertainty, such as blockchain implementation.

2. Clarifying the Role of Organizational and Environmental Drivers

Another contribution lies in the validation of specific TOE factors in the blockchain context. The model includes Top Management Support (organizational factor), Trading Partner Pressure and Competitive Pressure (environmental factors), as independent constructs influencing the Intention to Adopt Blockchain Technology. The empirical results confirm the strong and statistically significant influence of Top Management Support and Trading Partner Pressure, while showing a weak and non-significant relationship for Competitive Pressure. This finding contributes to the theoretical debate around external versus internal drivers of innovation adoption. Specifically, it suggests that in the context of blockchain, still an emerging and complex technology, internal strategic commitment and inter-organizational relationships are more influential than generalized market competition.

3. Intention as a Central Construct Linking Drivers to Perceived Outcomes

The thesis also reinforces the theoretical relevance of intention to adopt blockchain as a central construct in explaining how environmental and organizational stimuli translate into perceived benefits. Intention is shown to have a strong direct effect on both supply chain performance and transparency, indicating that organizational expectations regarding blockchain are not only shaped by external and internal pressures but also play a decisive role in projecting future benefits. This supports the idea, consistent with technology acceptance and innovation diffusion theories, that intentionality is a key bridge between strategic stimulus and expected outcome. Importantly, the study does not merely look at intention as a terminal variable but explores its influence downstream, thus providing a more dynamic and causally structured interpretation.

4. Positioning Perceived Transparency as a Strategic Construct

Although transparency is a recurring theme in blockchain literature, it is often discussed as a technical outcome (i.e., immutability, traceability, auditability). This thesis takes a different theoretical stance by treating transparency as an organizational perception, linked to the behavioral intention to adopt blockchain, rather than as an observed post-implementation result. This approach highlights that managerial decisions around blockchain are shaped by how technologies are expected to improve strategic attributes such as visibility, trust, and control within the supply chain, even before implementation. As such, the study proposes that perceived transparency improvement should be recognized as a distinct construct in the theoretical modeling of blockchain adoption, especially in supply chain contexts where trust and information asymmetries are central.

5. Context-Specific Contribution to Supply Chain Digitalization Literature

Finally, this research contributes to the broader body of work on digital transformation in supply chains by offering a conceptual and empirical model specifically tailored to the blockchain context. The inclusion of supply chain, specific outcome variables and drivers provides an applied extension to general adoption models. It also supports the idea that emerging technologies like blockchain are evaluated not only through technological or economic rationales, but through context-specific expectations, such as enhanced collaboration, improved traceability, and resilience.

5.3 Practical Implications

Several studies already proved the efficacy of block chain technology integrated in a mature organization. Nevertheless, this study's findings carry significant implications for both managerial practice and technology promoters. Organizations seeking to adopt blockchain in their supply chains should prioritize internal awareness and training programs to demystify blockchain and reduce psychological resistance to change. Moreover, they should ensure active involvement of senior management, not only in funding but also in communicating strategic alignment and long-term benefits. Another important aspect would be designing blockchain solutions with a high degree of interoperability, to minimize disruption to existing systems and processes. Lastly, it is critical fostering inter-organizational trust and transparency, even before formal adoption, to lay the groundwork for successful implementation.

5.4 Limitations of the study

Although this study provides valuable insights into the adoption of Blockchain Technology in supply chain contexts, several limitations must be acknowledged. First, although the survey was distributed internationally and reached respondents from multiple countries and sectors, the sample size remains relatively limited, which may affect the statistical generalizability of the findings. Future research could benefit from a larger and more balanced sample to enhance the robustness of the results

5.5 Future Research Directions

Building upon the findings and limitations of this study, several avenues for future research can be identified to deepen and broaden our understanding of blockchain adoption in supply chain contexts.

First, future studies should consider expanding the sample size and ensuring more balanced representation across industries and regions. Although the present research reached an international audience, some sectors or geographical areas may be underrepresented, limiting the possibility of generalizing findings to specific business environments. Comparative studies between regions, such as Europe, North America, and emerging markets, could reveal how institutional, regulatory, or cultural differences shape adoption behavior.

Second, future research would benefit from longitudinal designs that track how perceptions of blockchain, and related adoption intentions, evolve over time. This is particularly relevant given the rapid pace of technological change and the ongoing development of blockchain standards, regulations, and integration strategies.

Third, future research could enrich the current model by incorporating additional moderating and mediating variables, such as digital maturity or organizational culture. These elements may play a significant role in shaping how organizations perceive transparency and trust and could strengthen the explanatory power of the model.

Fourth, integrating qualitative research methods, such as case studies, expert interviews, or focus groups, could provide deeper insight into the contextual factors and real-world challenges that organizations face when evaluating or implementing blockchain. This mixed-methods approach would allow for a richer and more nuanced understanding of adoption dynamics that go beyond what can be captured through surveys alone.

In conclusion, as blockchain continues to evolve from a novel concept to a deployable solution, academic research must evolve accordingly, by embracing multi-dimensional models, broader contexts, and dynamic perspectives that reflect the complexity of real-world supply chains.

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