BLOCKCHAIN TECHNOLOGY AS A TOOL FOR SUPPLY CHAIN TRANSPARENCY

IN THE FASHION INDUSTRY:

ALIGNING WITH SDGS AND ESG GOALS

by

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Dedication

This dissertation is dedicated to all individuals who have profoundly influenced my academic journey and personal development.

I would like to express my deep gratitude to Professor Aleksandar Erceg for his unwavering guidance and support, which have been indispensable in shaping my research and enhancing my understanding of the academic landscape. His valuable insights have significantly contributed to my intellectual growth.

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This dissertation serves as a testament to the collective support and encouragement I have received from all those mentioned above. I extend my heartfelt thanks for being integral to my journey.

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ABSTRACT

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Dissertation Chair: Iva Buljubasic, PhD

This study explored the potential impact of blockchain technology in enhancing supply chain transparency and sustainability in the fashion industry, particularly in relation to its alignment with the Sustainable Development Goals (SDGs) and the Environmental, Social, and Governance (ESG) principles. In this respect, a mixed-methods approach was chosen, including a quantitative survey among 269 professionals working within fashion supply chains and qualitative expert interviews with representatives of brands, technology providers, and policy organizations. Descriptive studies, reliability tests, correlational questions, and regression modelling were used to analyze quantitative data. The findings indicated the large internal consistency among all of the constructs of blockchain capability. Blockchain Data Immutability (BDI) and Stakeholder Data Accessibility (SDA) emerged as the main predictors of perceived supply chain transparency. The thematic analysis of qualitative results indicated that mechanizations of trust establishment, regulatory compliance requirements, and multi-tier supply chain visibility represented some of the key drivers of adoption, technological adequacy, economics, and resistance among upstream suppliers, and key adoption barriers.

Even though blockchain is viewed as a provider of significant effects on traceability, real-time monitoring of compliance, and access to ESG data, the analysis showed that the current adoption is often confined to token projects or pilot programs. Full-scale diffusion is held back by the organizational inertia that persists in some organizations, digital illiteracy, and inefficient organizational governance structures. The findings were explained in the institutional category based on institutional theory and the resource-based view (RBV), which states the role of blockchain as a reaction to external forces and a possible strategic utility. At the same time, the Digital Product Passport (DPP) project offered by the European Union was also discussed critically as a regulation-driven alternative. Although DPP is a standardized method of

sustainability reporting, the study found that it cannot offer the decentralized data verifiability that blockchain does, which increases concerns of data credibility and the empowerment of stakeholders.

Adding empirical evidence of blockchain's operational and strategic implications in the context of fashion supply chains, the study also identified discrepancies between aspired potential and practices. The recommendations quoted the necessity of inclusivity of stakeholders, standardization of regulations, and governance based on ethics as the means to unlock the transformative potential of blockchain. The research aims to illuminate policymakers who can facilitate the adoption of scalable and sustainable blockchain solutions within the global fashion economy.

Md Aminul Haque
2025

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Chapter I: INTRODUCTION

1.1 Introduction

The fashion industry is a significant pillar of the global economy, currently valued at approximately USD 880.91 billion, with projections indicating growth to USD 1.18 trillion by 2029 (Statista, 2024). It is a vast and diverse sector that not only influences consumer behavior worldwide by shaping trends, identity expression, and lifestyle choices but also provides livelihoods to over 300 million people, many of whom are employed in garment manufacturing within emerging economies (Ellen MacArthur Foundation, 2019). Over the past decade, companies such as Zara and H&M have transformed the retail industry by adopting a fast fashion model, emphasizing rapid design, production, and distribution cycles to quickly respond to changing consumer trends at low prices. Louis Vuitton which occupied the position as the biggest clothing company in the world as of 2025 in terms of Market Cap with $282.97 billion, was in July 2025 superseded by Hermes (Statista, 2025). As the biggest clothing company in the world, Hermes now boasts of a market cap of $283 billion dollars, while Louis Vuitton has been pushed back to the second position, with a market cap of $267 billion (Statista, 2025).

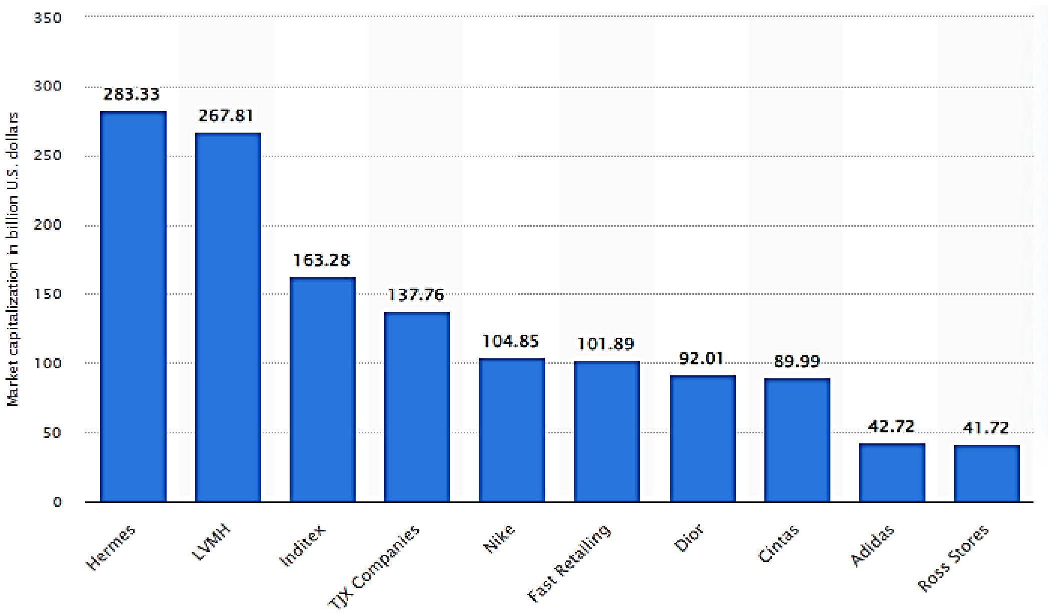

Figure 1: Leading Global Apparel Companies as per Market Capitalization
Source: (Statista, 2025)

Nonetheless, this system of operations has raised concerns about excessive output, waste creation, and exploitative labor. Supply chains nowadays are highly fragmented with many suppliers and third-party contractors, reducing transparency and accountability (McKinsey & Company, 2022). For instance, this was evident in the 2013 Rana Plaza collapse, where poor supply chain oversight exposed unsafe garment factory conditions (Asif et al., 2024). The interdependence of these networks and complexity creates unique operational challenges and causes difficulties monitoring the ethical and environmental standards at every production level. At the same time, the increasing attention of consumers and the changing landscape of regulators are putting more pressure on the sector to become more transparent and responsible in how it operates. Before the emergence of blockchain, the supply networks in the fashion industry were supported by a mix of digital and semi-digital tools for production tracking and governance of logistics. Barcoding and Radio-Frequency Identification (RFID) systems were widely used to enhance the inventory's accuracy, reduce shrinkage, and make it easier to manage the warehouse (Abdunabiev, 2024). Though barcoding provided a basic means of achieving an item-level traceability, RFID automatic identification and real-time visibility could be achieved even without a line-of-sight scan, thus making operational transparency to some extent (Ferdousmou et al., 2024). At the same time, fashion companies implemented Enterprise Resource Planning (ERP) solutions, which combined the financial, inventory, procurement, and logistical capabilities of different organizational departments. Applications like SAP or Oracle simplified the centralization of data anonymization of supply chain processes; nevertheless, due to the operationally centralized nature of these systems, they did not give end-to-end visibility within the global and many-tiered supply chains. For example, Inditex (Zara's parent company) uses SAP to integrate sourcing, inventory, and logistics in real time across global operations (Zhu, 2024).

Conventional systems of checking on ethical and environmental performance, such as auditing and certification, especially those of SA8000 and ISO, have also been used as regulatory standards (SAI, 2025). SA8000 and ISO (e.g., ISO 14001) are international standards that ensure ethical labor practices and environmental management in supply chains. However, such audits are conducted arbitrarily and are prone to exploitation, especially at facilities in distressed areas managed by loose observance. Moreover, Blockchain technology is now transforming industrial manufacturing with the creation of a decentralized and tamperable infrastructure to permanently store transaction history and supply chain information. Such an innovation enables the manufacturers to follow, in real time, the source and flow of raw material, manufacturing processes, and delivery activities. Blockchain reduces inaccuracy, fraud, and delays by discounting the need to use intermediate intermediaries and increasing transparency (Jenkins, 2023). At the same time, it improves cooperation between the partners of supply chain as well as enabling regulation of its adherence due to automatically written and checkable records. In an industry with the highest risk (textiles and fashion), where transparency and responsibility are key, it is a technology that makes brands, suppliers and consumers trust each other and thus meet increased societal demands for ethical and transparent sourcing.

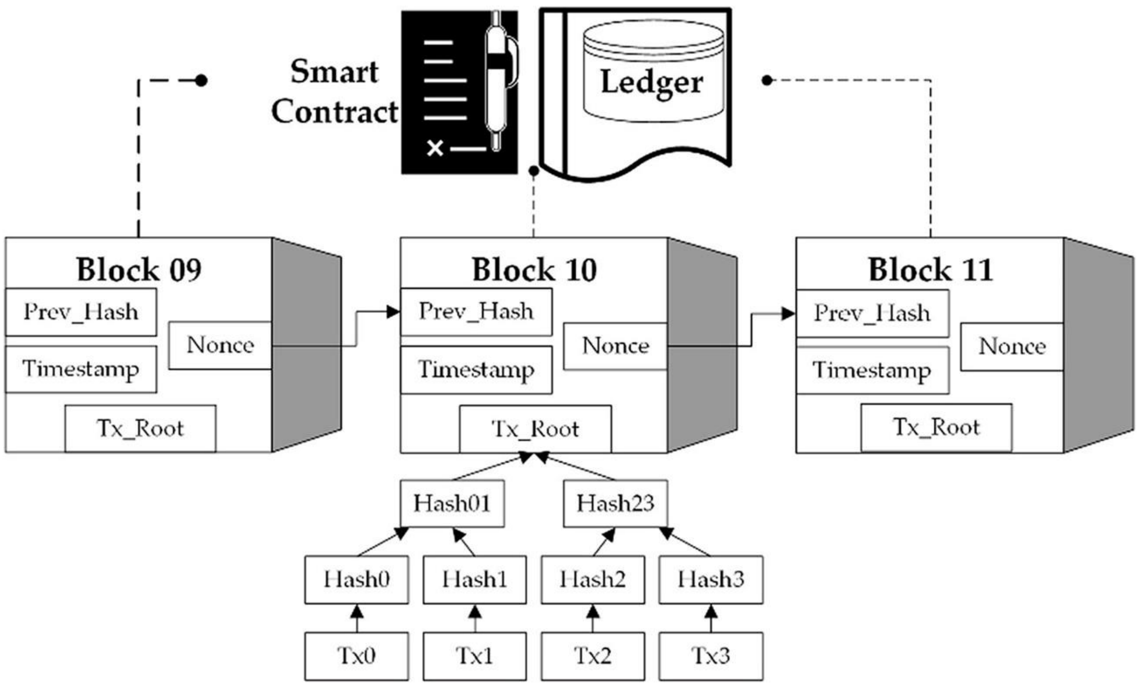

Figure 2: Typical Blockchain
Source: (Agrawal et al., 2021)

Regardless of establishing a foundation to enhance the overall efficiency of operations, Deloitte (2025) reports that legacy technologies fail to perform to the standards of blockchain's decentralized, tamper-resistant, real-time nature. Thereby, blockchain has increasingly become synonymous with the next level of digital transformation, as it is driven by the strength of multi-party traceability, the intrigue of greater transparency, and the automation of ensuring compliance, which none of the previous systems allowed (Saberi et al., 2019).

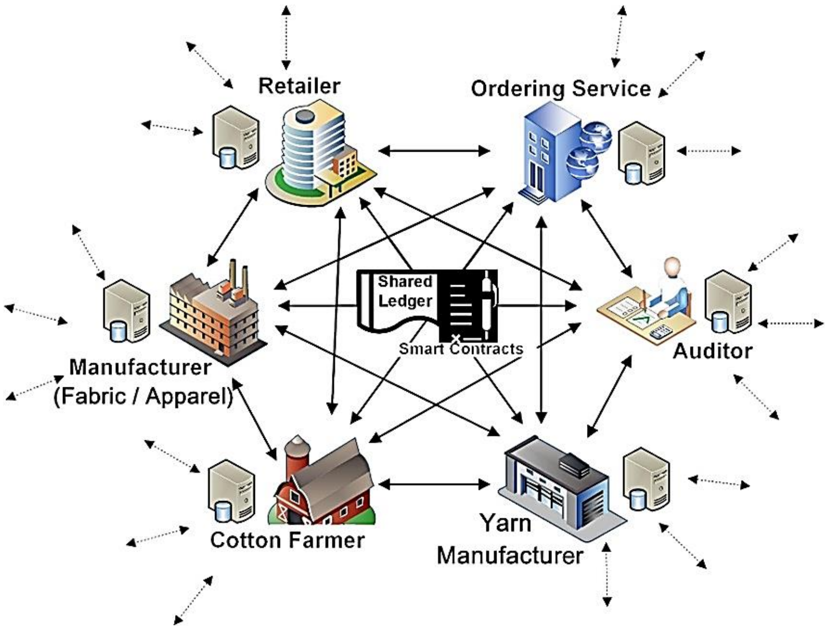

Figure 3: Blockchain-based Decentralized Information Sharing Network
Source: (Agrawal et al., 2021)

The fashion industry is well recognized as one of the biggest causes of mass destruction of the environment and injustice in society in the past few decades. According to the United Nations Convention to Combat Desertification (UNCCD, 2019), fashion causes about 10 percent of global carbon dioxide emissions, with the output of worldwide aviation and maritime transportation being significantly lower. The industry also contributes considerably toward water pollution; textile processing (dyeing and finishing) generates nearly 20 percent of all worldwide industrial wastewater, thus destroying river and aquatic ecosystems (Euronews, 2022). Moreover, fashion generates about 92 million tons of textile waste annually, and it is estimated that this level will rise to 134 million tons by 2030 if the current consumption rates continue (Igini, 2023). Social issues exacerbate such environmental predicaments. In many South and Southeast Asian countries where most of the world's garment production is done, workers often face hazardous working conditions, much lower wages, and poor union representation. These system problems were ever so clearly exemplified by the Rana Plaza catastrophe in 2013 in Bangladesh, where over 1,100 people lost their lives in a garment factory collapse (Asif et al., 2024). Despite the general outcry over this incident, which was felt worldwide, the rate and progressiveness of development in securing workers' rights, including safety rights, in the world have been uncertain and unverified to a great extent.

Various fashion houses have also endured criticism over wayward practices that are unsustainable and ethically dubious. The most noticeable case is provided by Burberry, which in 2018 declared that it had been burning unsold products worth 28.6 million to preserve the brand value, triggering harsh condemnation due to the created waste and pollution (BBC News, 2018). Similarly, H&M and other fast-fashion brands have been accused of using greenwashing and false sustainability practices as they uphold high production rates and significant environmental impacts (Changing Markets Foundation, 2022). These instances demonstrate how the difference between sustainability marketing and supply chain behaviors continues to grow. All these social and ecological disappointments demonstrate that a systemic change is needed. Technological interventions can only address the challenges, especially those that increase traceability and accountability. Without the help of open, real-time data integration, tracking the sustainability goals' compliance is tough.

During the past decade, customers have proven to be more sensitive about the ethical and environmental consequences of their purchasing decisions, creating an increasing demand for supply chain transparency. Child labor, environmental pollution, wage theft in the fashion supply chain, and other unethical practices have been taken to task by social-media advocacy, investigative journalism, and NGO reports. Consequently, significant numbers of customers have become demanding, particularly in becoming aware of the source of the goods and the way these goods are manufactured. A survey conducted by First Insight (2025) showed that 67% of Gen Z and Millennial respondents admitted that they base their fashion purchasing behaviors on sustainability. This increased awareness is alongside an increasingly high level of regulatory scrutiny. The Corporate Sustainability Due Diligence Directive (CSDDD) of the European Union requires major companies to detect and minimize human-rights and environmental risks in their supply chains (European Commission, 2024). A similar burden is put onto business entities by the Modern Slavery Act of the United Kingdom (2015), demanding issuance of statements at the end of every year, clearly outlining what is being done to prevent forced labor (Gov.uk, 2019). Through such legislation efforts, brands are encouraged to open their operations. The parallel forces coming up are also on the side of the investor community. Environmental, Social, and Governance (ESG) criteria are increasingly institutionalized in capital distributions. According to OECD (2023), sustainable finance has grown alarmingly, with investors clamoring about concrete, data-driven financial commitments of ethical sourcing and responsible production. The combined effect of all this pressure from consumers, regulators, and financiers has changed transparency from a voluntary ideal to a business condition.

Blockchain, as a decentralized digital ledger technology, has become an exploration vector in the fashion industry, which has increasingly become a probable solution to traceability and transparency. Some major fashion companies have implemented pilot blockchain applications to support responsibility and substantiate sustainability claims. The Aura Blockchain Consortium (2024) is a collaboration between luxury megacorporate LVMH, Prada, and Cartier, and illustrates one of the most significant blockchain projects within the industry. The goals held by the consortium include proving the product's authenticity, the ability to have traceable origins, and improved consumer confidence. The 2024 progress report suggests that over 30 million products have been tokenized via the program, and they have access to instant target product history by generating a QR code (Aura Blockchain, 2024). The initial findings indicate an increased consumer interest and brand loyalty, which LVMH confirmed in the rise of confidence in sustainability claims in labels, including Louis Vuitton and Bulgari (Danziger, 2024). Despite these developments, the advantages have been limited to luxury products and do not focus on scalability and the ability to participate in the mid-market or mass-market.

The partnership between IBM and a German textile manufacturer, Kaya & Kato, deserves to be an example of another blockchain-driven initiative aimed at end-to-end uniforms used by government employees. The pilot platform provided details about the procurement entities, such as material source, dyeing technique, and environmental impact. According to the evaluation of the trial conducted by IBM (2021), there was improvement in the compliance and supply chain visibility in the procurement processes. However, capital-expenditure needs and mixed levels of supplier digital maturity became limitations to broader adoption. Much to the pleasure of such research inputs, adoption setbacks still exist. Projects of many companies are in the early phases, and there is a complex process at the level of effective integration within the whole supply chain, especially with small suppliers in emerging areas. Moreover, there is little empirical evidence of long-term change in behavior or any measurable efficiency in the environmental impact of blockchain adoption alone. Blockchain architecture is an excellent basis for a trust system, but not a solution; it should be combined with ethical sourcing commitments, the onboarding of stakeholders, and proper regulatory networks to utilize this technology fully. Thus, although early endeavors in the fashion industry are showing progress in product validation and consumer trust, their effectiveness is limited to date by scale, accessibility, and standardization. Future scholarly research agendas must thus evaluate the possibility of pilot programs scaling to more comprehensive and industry-wide digital transformations creatively.

Blockchain technology has emerged as a transformative solution to several persistent challenges in the fashion industry, including enhancing traceability, preventing counterfeiting, and mitigating greenwashing practices. The fact that all the transactions or material progress is captured forever on the blockchain gives players in the industry access to tamper-proof data. These time-stamped data can be used to track the path of the garment back to raw material, distribution, and point of sale. This visibility boosts transparency throughout the supply chain and enables consumers to verify sustainability, ethical labor, and material provenance claims (Gariba et al., 2024). The main benefit of blockchain adoption is the ability to ensure sourcing and labor conditions verification using decentralized, immutable data and, in such a way, preclude the subsequent correction of the sustainability statements and hold accountability. The network also supports climate compliance strategies by documenting carbon emissions and consumption of resources at every level of production (Saxena et al., 2022). With the increasing pressure on major corporate apparel companies to improve the transparency of their supply chain, blockchain provides a common source of truth. It reduces reliance on separate reporting systems and third-party verifications. Moreover, blockchain also works as the enabler of automation by using smart contracts, which are self-executing contracts that come to life when specific criteria are fulfilled. These tools can automate ESG reporting processes, boost due diligence operations, and send alerts whenever there are violations or anomalies (Kaur et al., 2022). With the fashion industry having a multi-faceted and fragmented supply chain, the decentralized architecture of blockchain provides a practical solution to the lack of transparency and inefficiencies. In its wise application, it can validate and share ethical supply chains, fair labor, and low-ecology-making procedures in real-time.

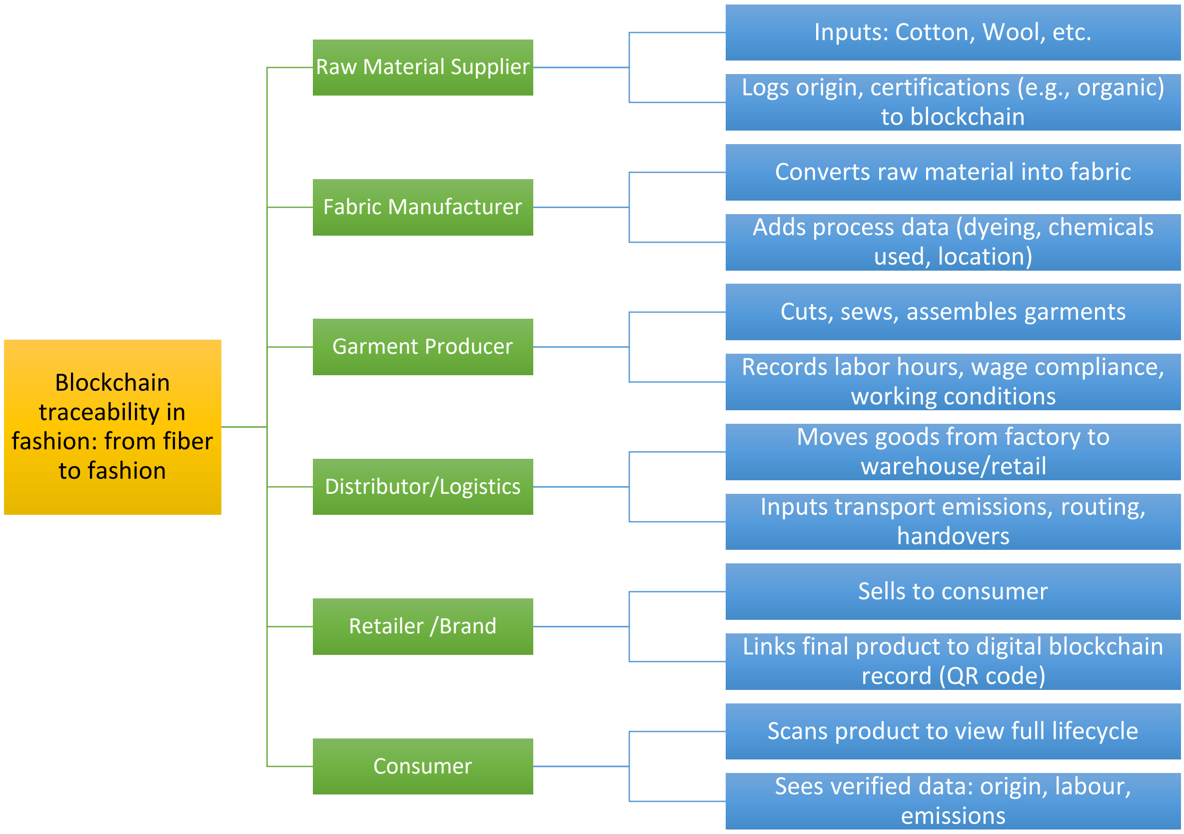

Figure 4: Blockchain Traceability in Fashion: From Fiber to Fashion
Source: Author's work

This diagram shows how blockchain helps trace a garment's journey from raw material to the customer. Key data (like origin, labor conditions, or transport emissions) is recorded on a secure digital ledger at each stage, from cotton farms to factories and retailers. This data cannot be changed later, ensuring transparency. When the product reaches the store, the customer can scan a QR code to see its full, verified history, making it easier to trust ethical and sustainable claims.

Blockchain technology is equally vital to stakeholders in achieving transparency and traceability when applied across fashion supply chains. Such stakeholders include suppliers, manufacturers, retailers, consumers, regulators, third-party auditors, and civil society organizations (Frishling, 2023). The first nodes of the supply chain include suppliers and raw material producers, most of whom are in developing countries (Kshetri, 2018). They must adequately document the inputs' source, the labor terms, and the environmental impact. The manufacturers involved in garment production must also record information on resource usage and governance practices. This kind of interaction ensures that blockchain records are not sparse but up-to-date. The retailers and brands, trading directly with the consumer, apply distributed ledger verification to verify the origins of products and sustainability statements and build trust to strengthen brand equity. The increasing need for transparency, especially with the Gen Z generation and millennial cohorts, has made transparent sourcing a sharp competitive differentiation feature. Policymakers and regulators, including the EU's Corporate Sustainability Due Diligence Directive, use blockchain-verified data as a supervisory tool that checks compliance with social and ecological standards. At the same time, third-party auditors and certifying agencies take advantage of the properties of a blockchain to reduce fraud and simplify the audit procedures (Gariba et al., 2024). For instance, when a factory upload verified data about worker wages and safety audits onto a blockchain, third-party auditors can instantly access this tamper-proof information without needing repeated manual checks. This reduces the chance of falsified documents and speeds up the audit process by providing real-time, verified records. Consumers are used not only as end users but also as active participants, who demand demonstration of total information transparency. Blockchain enables them to have real-time access to the products' journeys and the ethics that come with them. NGOs and activist groups, on their part, use distributed ledger datasets to track the violations, foster fair trading, and influence corporate behavior (George and George, 2024). All these dynamics require a collaborative model whereby all parties provide data, provide information, and gain mutually when the supply chain integrity is increased.

The fashion industry is a significant global trade, worth about US$880.91 billion in 2025 (Statista, 2024). Because of its considerable impact, the industry needs to follow global sustainability strategies. Two of the most important ones are the United Nations Sustainable Development Goals (SDGs), especially SDG 12 (Responsible Consumption and Production), and the Environmental, Social, and Governance (ESG) standards. It encourages the development of sustainable supply chains, increases resource efficiency, and decreases waste. Blockchain technology supports the goals of SDG 12 and ESG by ensuring accurate, tamper-proof data about each stage of the product's lifecycle, such as resource use, labor conditions, and environmental impact. This transparency helps brands prove they follow responsible consumption and production practices, reduces the risk of greenwashing, and supports compliance with global sustainability standards" (Shukla, 2025).

Blockchain proposed in the ESG aspect is a verifiable data solution in the three-pillar terms. To measure the Environmental (E) dimension, it captures footprints, resources consumed, water, and emissions. The Social (S) dimension has records of wages, labor conditions, and diversity measures. Regarding the Governance (G) dimension, it will collect auditing, certifications, and compliance information. Blockchain enables ESG data collection by embedding sensors, IoT devices, and digital reporting tools at each step of the supply chain. For example, environmental data like water use or carbon emissions can be recorded by smart meters installed at production sites, with data directly uploaded onto a blockchain ledger (Ma et al., 2023). Social indicators such as worker hours, wages, and compliance with labor standards can be logged using digital HR platforms linked to the blockchain (Azhar, 2024). Governance data such as third-party audits, certifications, or factory inspections are stored as immutable digital records, time-stamped and visible to authorized stakeholders. This ensures transparency, real-time monitoring, and tamper-proof ESG reporting. Automatic generation of these records makes it publicly verifiable, minimizes the reporting burden, and improves data integrity. In addition, the blockchain assists in adherence to the emerging disclosure requirements, i.e., the International Sustainability Standards Board (ISSB), the Global Reporting Initiative (GRI), and the EU Corporate Sustainability Reporting Directive (CSRD). Blockchain helps companies meet disclosure standards like ISSB, GRI, and CSRD by automatically recording verifiable ESG data in real time, reducing reliance on manual reporting and improving audit readiness (Li and Xu, 2025; Gariba et al., 2024). All these frameworks make sustainability reporting efforts highly stringent and auditable, which blockchain has the potential to fulfill. As a result, fashion businesses that embrace blockchain can move transparency up a notch and empower the trust of stakeholders, proactively adopting the industry challenges of increased regulatory attention.

1.2 Research Problem

Despite growing global concerns around ethics and sustainability, many fashion supply chains remain opaque, particularly in raw material sourcing, labor conditions, and environmental impact. Legacy systems ranging from paper-based records to fragmented digital tools fail to support real-time monitoring or reliable data validation. This lack of transparency presents not only an operational weakness but also a serious threat to corporate accountability and consumer trust (Nzuva, 2024). When a corporation has no idea about the conditions in its supply chain, it cannot implement strict sustainability or ethical standards. The insufficiency of supply chain transparency can be explained as an operational weakness and a disincentive to trust, hazard, and responsibility. An increased level of attention given by consumers, regulatory bodies, and investors requires fashion brands to support their pledge of ethics and sustainability. Traditional supply chain systems often rely on manual or disjointed digital workflows, which hinder compliance tracking and data integrity. As Gariba et al. (2024) argue, these fragmented systems contribute to regulatory delays, misreporting, and hinder traceability, ultimately compromising sustainability commitments and long-term brand credibility. According to Agrawal et al. (2021), the manual collection of the textile supply chain records makes verifying ethical or environmental compliance difficult. Several major fashion companies, such as Boohoo and Shein, have faced scrutiny for failing to ensure transparency and due diligence across their supply chains, illustrating the challenges organizations face in complying with regulations like the EU Corporate Sustainability Due Diligence Directive (CSDDD), which mandates firms to address human-rights and environmental risks across their operations (European Commission, 2024; Reuters, 2023).

Furthermore, in line with theoretical application, blockchain technology and its ability to create secure, immutable, and ledger-based blockchains have often been brought up as a corrective tool. Although blockchain has been widely recognized for its transformative potential in sectors like logistics and finance, its application to sustainability and ethical sourcing in fashion remains underexplored. Studies by Queiroz et al. (2021); Moretto and Macchion (2022) focus on technical logistics but fall short of addressing how blockchain supports responsible production aligned with SDG 12 or ESG indicators. Similarly, Moretto and Macchion (2022); Bucci (2019) examine blockchain approaches at the general level and do not focus on its viability as a process of ethical sourcing or transparent supply chains. This academic gap is highly pronounced: theoretical insights about blockchain capabilities remain insufficient when challenged directly by the context unique to the fashion industry. Experience of large-scale pilot programs such as Martine Jarlgaard, Armedangels, and C&A foundation-backed projects indicates technical feasibility. Still, there is a lack of understanding about their scalability or effectiveness in the long-term operation. This limitation is attempted to be resolved in the present study, where blockchain's ability to facilitate a transparent and ethical fashion supply chain within the long-term time horizons is examined.

Another barrier is the resource gap, which is biased in favor of large organizations, as they possess the financial, technical, and human capital needed to implement blockchain systems, resources often lacking in small and medium-sized enterprises (SMEs), limiting inclusive adoption and scalability. Bag et al. (2023) note that the small- and medium-sized enterprises that comprise a significant part of the fashion supply network often do not have access to digital infrastructure, money, and personnel needed to employ blockchains. Up to this point, adoption is limited to wealthy multinationals. There are limited cost-effective and feasible implementation plans even among the companies that intend to work with the blockchain. The criteria for evaluating blockchain's role in sustainability are also underrepresented. A critical limitation is the lack of standardized metrics for evaluating blockchain's contribution to sustainability. As Liu et al. (2023) warn, this absence enables inconsistent reporting and opens the door to greenwashing. Without unified benchmarks, brands can make unverifiable claims about ethical practices, undermining both investor confidence and consumer trust. Without standard metrics or regulatory mechanisms, policymakers and financial investors are facing a challenge of deciding to what extent blockchain promotes the adherence to ESG indicators or SDG 12. This must be made clear as ESG ratings may commonly require information regarding labor standards, carbon footprints, and material sourcing, all aspects that can be provided empirically using blockchain. This gap is targeted to be closed in the present study by determining the effective linking of blockchain data to ESG outcomes and SDG 12.

Putting it all in a nutshell, it is advancing slowly despite blockchain technology's technical capabilities to improve transparency and ensure ethical control over the entire chain of fashion processes. Lack of industry-specific applicability and standardized evaluation mechanisms forms research gaps to the full utilization. These limitations must be addressed to maintain the stakeholders' trust and improve the sector's ethical and environmental performance. Contemporary literature still points to the mismatch between the conceptual potential and the practical reality of blockchain in fashion supply chains. This gap further enhances greenwashing, where a company uses buzzwords about sustainability or incomplete statistics to seem more sustainable than its actions justify. Transparency must be used to combat this lie, but the verification mechanisms are inadequate. According to Singhe et al. (2022), blockchain has the potential to fill this gap, which, to a greater extent, still needs to be specified and registered.

One of the most significant weaknesses in the existing body of literature is a lack of studies that provide practitioner-oriented and detailed insights into the relationships uniting blockchain implementation with ESG results and consumer trust. Although Wang and Walker (2023) analyze how greenwashing undermines trust, not too many studies evaluate the potential of blockchain to revive trust by providing evidence that can be traced and verified. Bakarich et al. (2020) note that sustainability reporting with blockchain could improve using a tamper-resistant, decentralized ledger and report modification, but the empirical effect, especially in fashion, is scant. This means the struggle to relentlessly conduct research, particularly as the regulatory bodies also change the reporting requirements to be more stringent, is imminent. In addition to its technical factors, numerous human and organizational roadblocks are barriers to mainstream adoption of blockchain. In addition to technical obstacles, human and organizational resistance present a significant hurdle to blockchain integration. Sayilir et al. (2025) emphasize that widespread adoption requires cultural readiness, workforce training, and collaborative stakeholder engagement. Without addressing these dimensions, technological solutions risk limited impact. This study seeks to fill critical gaps by investigating how blockchain can enhance traceability and accountability in fashion supply chains. It aims to provide evidence-based insights into its alignment with ESG performance and SDG 12 targets, particularly by addressing scalability, evaluation standards, and organizational readiness challenges.

1.3 Purpose of Research

This investigative undertaking has been driven by the increasing demand for ethical, sustainable, and transparent supply chains, especially in the fashion industry, due to its environmental and social implications. Fashion annually produces millions of tons of textile waste, a quantity that is rising alongside the high-turnover fashion and mass manufacture. The produced goods doubled in 2000-2015, whereas the average garment lifetime reduced by 36%, highlighting overproduction and underutilization (UNEP, 2025). Clothing and textile products contribute to 11% of global plastic waste, yet in 2023, only 8% of raw textile fibers were derived from recycled materials (UNEP, 2025). All these trends indicate failures, such as the activity in the fashion supply chain. Most companies use older monitoring tools, such as management of resources, production, and supply, based on disintegrated chains of paper records, making traceability of their materials, audits of ethical labor, and immediate environmental impact assessment difficult. This type of fragmentation also promotes unethical processes such as greenwashing or worker exploitation, as the supply chain activity remains hidden. In addition, the traditional systems have limited protection against data alteration, which is a prerequisite for believable sustainability verification.

The research examines blockchain technology as a potentially strong tool in providing increased visibility to the fashion supply chain and assisting the fashion industry in achieving the global sustainability goals, specifically SDG 12, Responsible Consumption and Production, and the comprehensive ESG markers. In fashion, unique operating needs, which include multi-layered supply chains, extreme seasonal variability, and fast-paced production schedules, make it so that we can never have too much visibility up and down the production chains (McKinsey and Company, 2022). However, the current adoption of blockchain among fashion organizations is relatively low and limited mainly by the uncertainty that plagues both use cases and scalability (Saxena et al., 2022). The current study, therefore, seeks to overcome these shortcomings by offering industry-focused information about blockchain adoption that can be used to develop meaningful and effective deployment processes.

To guarantee corporate accountability, governments and international organizations have established strict rules and regulations; this is enforced by the Corporate Sustainability Due Diligence Directive (CSDDD) of the European Union and the Modern Slavery Act of the United Kingdom. The two require companies to identify, avert, and correct human-rights and environmental injuries. Businesses need reliable, non-editable data to observe, and blockchain can offer such a service. However, the current literature has not exhaustively investigated the potential of blockchain in meeting these international benchmarks within the fashion industry. The available literature is either general about blockchain or a study on topics in sectors like finance or manufacturing. Singh et al. (2022) explain blockchain concepts in fashion yet fail to review practical results. Wang and Walker (2023) discuss the mistrust of consumers after the cases of greenwashing but overlook its technical solutions. In their turn, George and George (2024) discuss the possibility of traceability and real-time monitoring but do not provide an all-in-one framework for fashion businesses.

The research, therefore, aims to fill in these gaps by investigating how blockchain can enhance supply chain transparency in the fashion industry and how businesses can achieve sustainability standards through it. The distinct supply chain configurations in the fashion industry, seasonality, and quick production cycles highlight the need for good transparency mechanisms. Still, even though these imperatives exist, adoption is somewhat restricted. The study will also consider obstacles to implementation and measures that can be taken to implement the technology successfully, not to mention the overall applicability of the technology to address modern policy needs. Compared with how it has already been used, blockchain technology has significant potential to improve transparency throughout the fashion supply chain; however, it still has far to go in this objective. According to the results of large-scale experiments of such brands as Martine Jarlgaard and Armedangels, even at a technical level, blockchain solutions can track garments at every stage, including at the design stage and during retail activities Ahmed and McCarthy (2021). However, it remains an open question whether these systems can be even practically feasible at the industry level, and it makes sense to investigate governance structures, financing arrangements, and normative systems of their application.

Addressing the barriers to widespread adoption, Bag et al. (2023) highlights that many small and medium-sized enterprises (SMEs) lack the financial resources, technical infrastructure, and internal expertise required to implement advanced technologies like blockchain. Consequently, most firms cannot move beyond the exploratory stage or conduct feasibility studies, making it challenging to initiate even pilot projects. Furthermore, there are no measurements everyone accepts, which makes a consistent evaluation of the extent to which blockchain favors environment, social, and governance (ESG) or sustainable development goals (SDGs) impossible. Liu et al. (2023) show that a lack of similarity in accounting mechanisms makes it difficult to compare or validate the sustainability performance in different organizations; this difference will undermine the confidence of the stakeholders and promote unethical behavior due to a lack of visibility of anomalies.

A future Digital Product Passport (DPP), part of the EU Green Deal and Eco-design for Sustainable Products Regulation (ESPR), will be used, theoretically, to implement extended transparency of the product cycle within textile supply chains by 2027. The DPP also enforces a centralized structure-based data collection regime upon regulated firms throughout the life cycle of their products, including raw materials extracted, and at the end of life (EPRS, 2024). The DPP claim to provide strong governance but given their commitment to fixed reporting structures and the prescriptive compliance signals, they may not align well with the multi-leveled and foreign supply chain environment of global fashion industries, especially with small- and medium-sized companies (SMEs) or those that are not in the EU (Worldly, 2023).

In stark contrast to this, this paper considers the progressive approach of blockchain, which entails a decentralized technology platform, real-time traceability template, automation of ESG declarations, which occurs via smart contracts, and multi-party permit access without relying on a central authority. The decentralization used here increases trust and reduces the dependency on third-party certifications, bringing more transparency and immutability to the structured reporting model used by DPP. In addition, the decentralized character of blockchain ensures that supplier information of countries other than the EU, such as Bangladesh, Vietnam, and Pakistan, which exhibit governance and resource-related shortfalls that undermine the effectiveness of traditional audit methods, can be accommodated.

The main strength in terms of competitive advantage of the proposed research is a prototype that could be developed based on blockchain-based traceability, be in line with SDG 12 and ESG metrics, and interoperate with DPP systems. This hybrid competency provides fashion firms with hybrid preparedness to pre-empt the use of scalable digital infrastructures before fully enforcing DPP, thus enabling them with a policy-compliant and future-proof solution. Eventually, the project would be the basis of developing an open access blockchain application that could be tested at the level of fashion retailers, providing processes to achieve global sustainability goals and EU regulatory alignment efficiently and in a coordinated fashion.

1.4 Significance of the Study

The current research addresses significance through combining technological innovation, namely blockchain, and sustainable supply chain management in the fashion industry. Employment of both Institutional Theory and Resource-Based View (RBV) would promote theoretical contribution of the research, namely the articulation of the idea of how the combination of external forces (regulatory pressure, industry norms) and the internal resources (blockchain capabilities) could be used as the motivation and structure the adoption process. This dual-theory prism transcends the descriptive accounts and offers facts on how blockchain simultaneously benefits as a strategic resource and legitimacy mechanism in the sustainability endeavor of the fashion industry. Moreover, the research promotes methodological rigor, as it follows a mixed-research approach, including surveys and interviews, to provide more insights into blockchain's functional and strategic influence. That would be in line with Creswell and Plano Clark (2018); Dawadi et al. (2021) and the lack of empirical balance that previous research has Singh et al., (2022); Gariba et al., (2024). An academic contribution of the study lies in the innovative aspects of blockchain-based traceability, smart contracts, ensuring ethical compliance, and validating the validity of ESG reporting tools. Such insights can inform future research on technological adoption practice, sustainable practice, and fashion management research.

The study offers valuable insights to fashion companies, retailers, and technology providers who can use it to understand how they can implement blockchain to improve transparency, minimize the threat of greenwashing, and promote their claims to sustainability. ISS (2024) states that over 90% of a company's greenhouse gas emissions originate from its supply chain activities. Blockchain provides a trustworthy means of tracking ethical activities and ESG involvement. Examples of case offerings of in-fashion pilot-style traceability solutions, such as LVMH Aura consortium and IBM, KAYA & KATO, showcase how such offerings may be piloted. However, Treiblmaier (2019) explains that large-scale blockchain adoption remains uncommon due to high implementation costs, lack of technical expertise, and interoperability issues. Many firms struggle to integrate blockchain into existing systems, and without clear regulatory frameworks or proven ROI, companies hesitate to move beyond pilot stages. The study focuses on obstacles associated with integration costs, fragmentation, SME readiness, and governance misalignments, giving decision-makers systematically tested recommendations to develop scaled blockchain projects that would fit fashion supply chains. The results involving new contracting formats, interoperability guidelines, and coordination among stakeholders also provide a point of reference for implementers on practically addressing the tensions between transparency, cost, data privacy, and ESG metrication.

This operational study defines methodical routes to expand traceability, reduce fraud engagement, and computerize ESG reporting using blockchain-based instruments. Using blockchain's tamper-proof ledgers and smart contracts, companies can automatically track product origins, detect anomalies, and generate real-time ESG compliance reports accessible to all stakeholders. Positively correlated with ethical results, the report provides valid justification to automate trackability of raw materials to retail, with the message reducing the likelihood of delays, misreporting, and greenwashing. Similarly, Gariba et al. (2024) emphasize that traceability is essential to sustainable digital transformation. At the same time, the research demonstrates how real-time blockchain tracking can help managers make decisions related to investing in the digital infrastructure available in SMEs, thus establishing accountability, reducing supplier risk, and allowing proactive monitoring of labor and environmental policies. These results echo resource-lean traceability implementation, especially when combined with strategic decision-making and risk management systems.

As global pressures to understand supply chains continue to grow, the study is well placed to inform the debate over the utility of blockchain to support regulatory checks. This aligns with emerging requirements from frameworks such as the EU Corporate Sustainability Due Diligence Directive (CSDDD) (European Commission, 2024), the UK Modern Slavery Act 2015, as stated by Gov.uk (2019), and recent disclosure standards from the International Sustainability Standards Board (ISSB) and Corporate Sustainability Reporting Directive (CSRD) (EFRAG, 2025). Furthermore, research into the role of blockchain in internalized ESG data metrics, smart contract-enabled audits, and decentralized verification mechanisms can assist regulators and enforcement bodies in strengthening monitoring practices. These insights are critical as discussions expand around digital infrastructure grants to SMEs, standardization of blockchain interoperability for sustainability reporting, and global harmonization of audit frameworks (Bag et al., 2023). Furthermore, blockchain initiatives that align with the UN SDGs and ESG protocols enhance timely, verifiable, and tamper-proof corporate disclosures (George and George, 2024), thereby increasing the trust of investors and regulators in reported sustainability claims.

Saxena et al. (2022) mentioned the promising nature of blockchain in ESG contexts, although they pointed out that there is no uniform measurement. This paper fills that gap by proposing and testing transparent metrics connecting blockchain data with ESG metrics like carbon emission, water consumption, wage compliance, and audit scores. The empirical application of these metrics as a survey helps the study to come up with validated instruments to be used by scholars and practitioners to benchmark the ESG impact of blockchain. The results provide a significant input in bridging the identified gap in standardization and the emergence of audit-ready reporting systems (Liu et al., 2023).

Other than the direct ramifications to the fashion sector, the significance of this research also lies in shaping future architecture of sustainable digital economies. With the inclusion of blockchain as a data pillar, this research offers a path for its interoperability with forthcoming regulatory tools like the EU Digital Product Passport (DPP), facilitating organizations to be at par with budding policy environment prior to the overall materialization of the mandate. Furthermore, validated ESG-linked blockchain metrics and methodological framework developed are not restricted to apparels alone but it also has relevance across sectors, including industries like pharmaceuticals, food, and electronics, who are known to be confronted with challenges of fragmentation in supply chains, traceability issues, and the threat of greenwashing. A wider applicability increases the significance of this research, as it is not only useful to tackle the distinct problems of fashion, but it could also be instrumental in developing a replicable model pertaining to blockchain-facilitated sustainability reporting, which has the potential to hasten a systemic change within global supply chains.

1.5 Research Purpose and Questions

The research critically evaluates the role of blockchain technology in increasing transparency and traceability of the global supply chains of the fashion sector. The fashion supply networks, characterized by their complexity and lack of transparency, link the suppliers of raw materials, manufacturers, distributors, and retailers without a chain of accountability on ecological sustainability issues and fair labor practices. Those gaps have become particularly important since treating corporate social responsibility and being environmentally sound are a worldwide focus. This analysis aims to respond to the critical need for ready-to-apply realities that can track, record, and check all aspects of production. Increased consumer awareness, regulation, and stakeholder demand on Environmental, Social, and Governance (ESG) indicators put intense pressure on companies to prove legitimate ethical conduct. Nonetheless, outdated tools such as paper-based logbooks, limited-scope audits, and decentralized electronic databases are unchangeable and insufficient to support verification in real-time. A promising alternative is blockchain technology, which is decentralized, immutable, and non-time-consuming when sharing data. It can reduce data manipulation and increase participant trust by allowing several stakeholders to record, access, and authenticate transactions without a central authority. This research examines the potential of blockchain-based tools such as smart contracts, digital provenance systems, and token-based certifications to meet Sustainable Development Goal 12 (Responsible Consumption and Production) and ESG objectives. Furthermore, it evaluates the viability and limitations of the usage of blockchain, especially for small and medium enterprises (SMEs) that lack the resources or infrastructure to achieve digital change. Large-scale implementation often suffers because of price, compatibility, data standards, and technical skill. The outcomes of successful pilot projects and first adopters are reviewed to pinpoint the factors that facilitate and the key obstacles to success and establish best-practice recommendations towards future strategies. Academically, the research brings blockchain innovation together with the scholarship of sustainable supply chain. The theoretical and practical insights furnished by the analysis through the perspective of the Institutional Theory to discuss the presence of external pressures (including the regulation and consumer expectations) and the Resource-Based View (RBV) to reveal blockchain as a strategic internal competence can deliver a valuable piece of theoretical and practical guidance to researchers, practitioners, and policymakers who are eager to align technological progress with the global sustainability goals.

1.5.1 Research Question

How can blockchain technology improve supply chain transparency and traceability in the fashion industry, supporting the advancement of SDGs and ESG goals?

1.5.2 Research Objectives

1. To examine the features of blockchain technology and evaluate its potential to enhance transparency and traceability in fashion supply chains.
2. To analyze the key challenges hindering the adoption and scalability of blockchain technology within fashion industry.
3. To explore real-world case studies applications of blockchain in fashion supply chains to understand implementation practices.
4. To evaluate the alignment between blockchain-enabled supply chain transparency and global sustainability frameworks, particularly Sustainable Development Goals (SDGs) and Environmental, Social, and Governance (ESG) goals.

1.5.3 Hypothesis

H1: There is a positive significant impact of Blockchain Traceability Capability, Data Immutability, Smart Contract Automation, and Stakeholder Data Accessibility on supply chain transparency.

Hypothesis 1 is based on the key functionalities of blockchain technology which directly address long-standing issues pertaining to gaps in transparency within global supply chains, especially in the global fashion sector. The traceability feature of blockchain facilitates products to be tracked in real-time, right from the sourcing of raw materials to eventual sale, thus lowering any opaqueness and improving visibility within the value chain (Song, Sung and Park, 2019). Such transparency has a dual purpose wherein it not just enables brands to ascertain ethical sourcing but it also doubly assures consumers about the sustainability and authenticity of products (Saberi *et al.*, 2019). Immutability of data tends to reinforce this procedure by making sure that all information that has been recorded cannot be tampered with and can be verified, thus nurturing trust within stakeholders and thwarting any unethical or fraudulent practices. Efficiency is enhanced with smart contract automation when predefined contracts are automatically executed, without the involvement of any intermediaries. This helps in diminishing the scope for delay and augmenting accountability at the same time (Groschopf, Dobrovnik and Herneth, 2021). Lastly, data accessibility of stakeholders is instrumental in ensuring that all pertinent stakeholders (suppliers, retailers, consumers) are in a position to access precise, synchronized information, encouraging cumulative responsibility and decision-making which is informed. Such features collectively improve transparency by reducing any asymmetries in information, ensuring auditability, and augmenting the integrity of supply chains. Therefore, it would be rational to hypothesize that the technical capabilities of blockchain make a significant positive impact on supply chain transparency, which is a crucial aspect in realizing responsible sourcing and operational accountability within the sector of fashion.

> H2: There is a positive significant relationship between Blockchain Traceability Capability, Data Immutability, Smart Contract Automation, Stakeholder Data Accessibility with SDG 12 and ESG goal.

Hypothesis 2 is backed up with the growing acknowledgement of blockchain as one of the foremost facilitators for responsible and sustainable systems of production. As per SDG 12, the need for responsible production and consumption, which is at par with the necessity to have ethical, transparent, and sustainable supply chains within the fashion sector. The traceability capability in blockchain allows brands to track social as well as environmental impacts at every phase of production, which supports waste reduction and sourcing sustainable materials (Barretti *et al.*, 2023). Data immutability is key to ensuring credibility in claims pertaining to supply chains, allaying the issue of greenwashing and fostering adherence with benchmarks for ESG reporting (Mattila *et al.*, 2021). Through process automation with the help of smart contracts, organizations will be in a position to impose sustainability benchmarks and compliance on the part of suppliers without any need for manual intervention. This would be beneficial to ensure continuous compliance with ESG obligations (Yu, 2024). Moreover, with data accessibility for stakeholders empowers regulators, investors, and consumers to validate metrics pertaining to sustainability, enhancing corporate reputation and accountability. The increase in transparency supports the incorporation of ESG goals within business strategies, thus bringing about a systemic modification towards responsible production and consumption. In this manner, blockchain emerges as a technological infrastructure that enables measurable advancements in SDG 12 and indicators for

ESG performance. Thus, a robust positive association between blockchain capabilities and SDG and ESG goals are theoretically as well as practically valid.

CHAPTER II: REVIEW OF LITERATURE

2.1 Introduction

The pace of industrial digitization has fueled the development of an increasing academic and business nexus surrounding blockchain as a disruptive technology that can temper the decades-old transparency gap in supply chain management. In the fashion industry, the growing demands of addressing its environmental impact, ethical production, and compliance with regulations have made blockchain acceptable in achieving trust, traceability, and responsibility (Oriekhoe et al., 2024). This critical review thus attempts a critical evaluation of the existing literature and finds areas of conceptual, technological, and practical concepts that support the possibilities of blockchain in enhancing sustainability in the fashion supply chain. The idea is to bring together existing discussions to outline research gaps and to position the particular study in the context of wider academic and practical development, especially concerning the Sustainable Development Goals (SDGs) and Environmental, Social, and Governance (ESG) initiatives. Even though the concept of sustainable governance in fashion has traditionally been viewed through artistic-creative and economic prisms, a multidisciplinary approach, which encompasses the fields of information systems, operations management, digital innovation, as well as environmental science, is no longer optional (Kalkanci et al., 2019). The industry's sheer size, the fragmented way it runs its operations, and the underlying visibility and accountability issues make blockchain a highly strategic, not to mention purely technical, intervention.

The method of a systematic review is as follows: the anchor in theory on Institutional Theory and Resource-based View (RBV) is established; the historical development of blockchain and technological properties are outlined; barriers to its integration connected to a specific industry are described; the compatibility between blockchain and sustainability structures is questioned; and the case studies are elaborate. The review compares and contrasts the European Union Decentralized Policy Platform (DPP) with decentralized blockchain systems, demonstrating the potential for hybrid systems to resolve regulatory compliance with globally scalable and tamper-resistant traceability in fashion supply chains. In the final section, the most notable research gaps and literature will be mentioned, the current work will be positioned in the broader context, and the prospect of further methodological and empirical studies will be provided.

2.2 Theoretical Framework

To enhance the theoretical soundness of the proposed research, there is a pressing need to establish how Institutional Theory and Resource-Based View (RBV) operate as parallel but analytically fitting concepts. The Institutional Theory is very relevant since it explains how external forces induce fashion companies to accept blockchain to convey the message about being on the right side of the house, gaining legitimacy, and overcoming reputation risk based to regulatory mandates (e.g., CSDDD), pressure by activist consumers, and ESG reporting pressures (DiMaggio and Powell, 1983). In apparel and footwear, where environmental and labor-related scandals drive the increased levels of institutional isomorphism, blockchain can become a strategic reaction to it. At the same time, RBV contributes to the internal-oriented analysis on integrating blockchain, focusing on firm-specific sources, including the IT infrastructure, qualified human resources, and digital governance, and evaluating the viability and effectiveness of implementation (Barney, 1991). This school of thought explains how differences in performance in terms of adoption exist between large fashion enterprises and SMEs. A combination of these frameworks offers comprehensive boundaries of the incentives to adopt, and the organizational preparedness and abilities, facilitating a high-impact questioning of compliance in the institution and generation of strategic value that complements the research stream on sustainability in SDG 12 and ESG requirements.

2.2.1 Institutional Theory

2.2.1.1 Origins and Core Concepts

The original formulations of the Institutional Theory by Meyer and Rowan (1977) and further developed by DiMaggio and Powell (1983), are an essential tool in understanding organization behavior under external limitations. The theory suggests that these institutions define the rules that the organizations should adhere to so as to realize legitimacy and social acceptability. The diffusion of similar structures and practices can be attributed to three main different forms of institutional isomorphism such as coercive, normative, and mimetic ones. Coercive isomorphism is founded on formal pressures, including regulations and legal requirements; normative isomorphism is based on professional norms and industry constraints; mimetic isomorphism arises when organizations follow successful exemplars, especially in uncertain circumstances (DiMaggio and Powell,1983). The theoretical approach disagrees that organizational action is only influenced by economic rationality but in most cases, it is in line with socially defined norms and expectations. As a result, such a perspective can explain the development of sustainability tools such as blockchain not only as a means of garnering profit but also a means to appear trustworthy and responsible, especially in industries known to be affected by ethical concerns such as fashion. Therefore, institutional Theory clarifies the impact of external pressure on regulators, consumers, and industry norms in shaping the process of acceptance of blockchain among fashion firms as an approach to boost transparency and fulfill the expectations of sustainability.

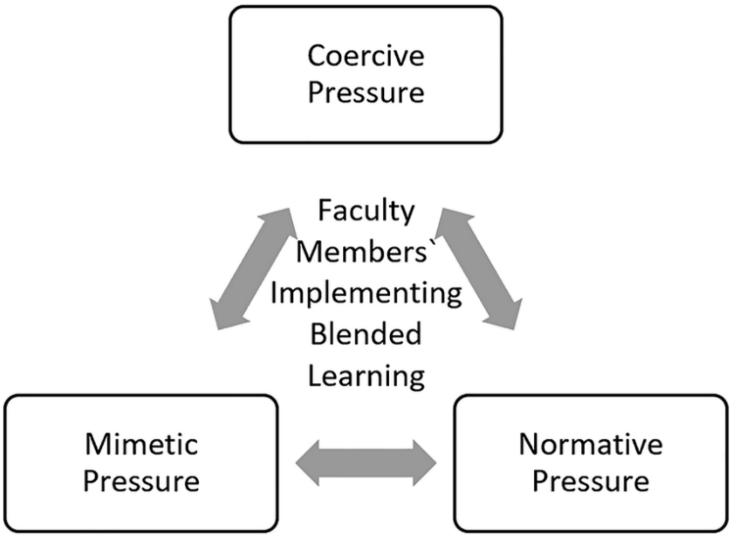

Figure 5: Components of Institutional Theory
Source: Anthony Jnr (2021)

2.2.1.2 Relevance to Supply Chain Sustainability in Fashion

The global fashion industry has now come under intense institutional spotlight due to its complex supply chains that are commonly associated with environmental destruction and exploitation of laborers'. Ethical sourcing and transparency of supply chains have gained more momentum due to an escalated voice by governments, non-governmental organizations (NGOs), activist investors, and civil society. Examples of legislative efforts to enforce sustainable due diligence include the proposal of the European Union (2022) Corporate Sustainability Due Diligence Directive (CSDDD) and the UK Modern Slavery Act (2015) which compel companies to map and report environmental and human rights violations along their supply chains (European Commission and the European Parliament, 2024; UK Government, 2019). Due to the widespread adoption of reporting frameworks such as the Global Reporting Initiative (GRI) and ESG reporting disclosure, normative expectations have also stepped up in terms of increased demands on the report or the report-holder.

Simultaneous to such normative expectations, there has been an amplification in institutional pressure by the investor community (Shi and Mai, 2025), wherein they channel capital to organizations with proven ESG performance, rendering sustainability reporting not only a reputational but a financial necessity. Nonetheless, it has been indicated through research that several fashion organizations frequently resorted to ‘symbolic compliance’, by providing certifications or reports on sustainability which satiated reputational or regulatory requirements (Dobos and Éltető, 2023). However, this would be without realizing significant enhancements on the ground. Such a discord between actual practice and disclosure outlines the need for tamperproof and verifiable systems such as blockchain that can overcome the chasm between institutional requirements and genuine sustainability performance.

In addition, consumer activism such as boycotts, brand shaming campaigns on social media and so-called endorsement boycotts, have increased the reputational risk of fashion brands (Kourula and Delalieux, 2016). Such forces establish an environment in which the adherence to the norms of sustainability is not a choice but a strategic necessity. It is increasingly being perceived by the fashion brands in international markets that sustainability related communication and traceability are ways in which they keep behind to the side sustainability related disclosures. Thus, supply chain sustainability is not merely an ethical requirement but a reaction to multi layered institutional pressures making Institutional Theory an adequate methodology to consider when regarding blockchain adoption in the industry.

2.2.1.3 Legitimacy Pressures Driving Blockchain Adoption

Blockchain technology has proved to be an auspicious tool to enable fashion companies to present burgeoning pressures of legitimacy. Being a decentralized and tamper-proof architecture, Afrin and Pathak (2023) present that blockchain ensures that global supply chains are provided with the dire necessity to trace, audit, and prove authenticity. Mandatory due diligence and transparency laws, like the EU CSDDD, use coercion to compel companies to institute methods that can be used to systematically monitor human rights violations and environment effects (EPRS, 2024). Enablers of blockchain verify compliance, along with documentation of supplier information in real-time and providing safe access to the auditors and regulators. Normative activities are also important: supply chains are important to industry standards and sustainability certifications, and blockchain offers a way to comply with those commitments with a verifiable supply chain at the same time (Saberi et al., 2019). The development of digital product passport and new generation of labeling platforms further support this change. Mimetic isomorphism in which organizations imitate the structure and practices at successful firms is observed in enterprises imitating such trendsetters as LVMH, a co-founder of the Aura Blockchain Consortium, and Adidas that piloted traceability blockchain with their partners like Circular Fashion (Aura Blockchain Consortium, 2024). These companies serve as the models of legitimacy and push other companies towards the deployment of similar technologies, not often in reaction to proving returns on investment but in an effort to remain competitive and credible.

As far as the social aspect of sustainability is concerned, there have been innumerable instances of human rights violations across industries, including the fashion sector. It has been reported by the International Labor Organization, that around 79 million children are known to work in extremely unsafe working conditions (ILO, 2023). As a matter of fact, child labor is prevalent in the readymade garment (RMG) export supply chains in Bangladesh, it has been reported through a study (Goodweave, 2025) that around 100% of the minors who participated in the survey were employed illegally as child laborers in the RMG sector. At the same time, around 32% of adults engaged in the RMG sector were paid less than the minimum stipulated wage. Given these factors, the pertinence of the social dimension is vital for the fashion sector, necessitating them to safeguard human rights, while ensuring employee welfare. This aspect acts as a pressure on organizations to adopt blockchain technology.

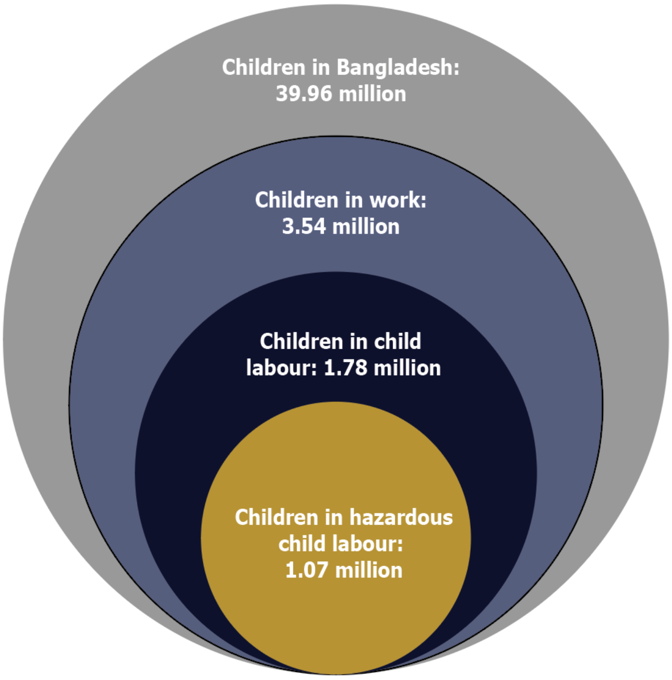

Figure 6: Child Labor Statistics in Bangladesh
Source: (Goodweave, 2025)

Furthermore, there are regulatory pressures as well which comprise pressure from diverse institutions, wherein organizations are compelled to adhere to regulations on sustainability. This at times also tends to hamper the pursuit of sustainability (Bucci, 2019). Other legitimacy pressures might include market pressures wherein organizations and its supply chains are forced to embrace sustainability.

From this context, blockchain technology can also be instrumental in trancing potential social and environmental conditions which can present a risk on health and environment. Therefore, the blockchain not only provides valuable technical assistance but also serves as a well-established indicator of corporate responsibility, allowing companies to earn the trust of the masses and meet the demands of the regulators.

2.2.1.4 Application in Blockchain and Fashion Context

Institutional Theory increasingly attracts scholars to ask questions about blockchain adoption in various industries, particularly where legitimacy and external compliance matter most (Treiblmaier, 2019; Bai and Sarkis, 2020). The same framework in the case of fashion industry explains why the firms adopt the use of blockchain despite a lack of direct or immediate monetary benefits. Institutional pressure to carry out technology is more often than not driven by institutional imperative than a strictly cost-benefit factors that come into play (Diakiv, 2024). An example is the increasing utilization of blockchain to address the required Environmental, Social and Governance (ESG), disclosures and sustainability reporting regimes, such as the Global Reporting Initiative (GRI) and Corporate Sustainability Reporting Directive (CSRD) in the European Union (Jenkins, 2023). These paradigms create a situation whereby traceability and compliance is demonstrable where it becomes a precondition in participating in each market and gaining investor trust. In that respect, Institutional Theory can help to overcome discontinuity between normative motives and reality of technological uptake thus drawing attention to symbolic role played by blockchain as a means of achieving organizational legitimization. As a result, the analytical perspective presents a better insight into the social and institutional processes that lie behind the adoption of blockchain in the fashion sector.

2.2.2 Resource-Based View (RBV)

2.2.2.1 Origins and Core Concepts

The Resource-Based View (RBV) is a foundational theory in strategic management developed by Wernerfelt (1984), later refined by Barney (1991), which asserts that a firm's competitive advantage arises from the possession and strategic deployment of valuable, rare, inimitable, and non-substitutable (VRIN) resources. Unlike external positioning theories, RBV centers on the firm's internal environment, asserting that organizations achieve superior performance when they utilize unique resources and capabilities that competitors cannot easily replicate. Rehman et al. (2022) asserts that in the modern digital transformation and sustainability context, intangible resources such as technological competencies, data analytics, and supply chain innovation are increasingly pivotal. Blockchain, with its decentralized architecture and tamper-proof design, aligns with RBV as a technology-driven resource that can elevate organizational differentiation and long-term sustainability performance. It also embodies the VRIN attributes, its immutability ensures trust (value), it is yet to be widely adopted across the fashion sector (rarity), difficult to duplicate without similar IT and governance capacity (inimitability), and substitutes offering equal auditability are limited. RBV clarifies how internal capabilities such as technological infrastructure, expertise, and strategic assets enable firms to effectively implement blockchain and derive competitive advantage through improved supply chain transparency and ESG alignment.

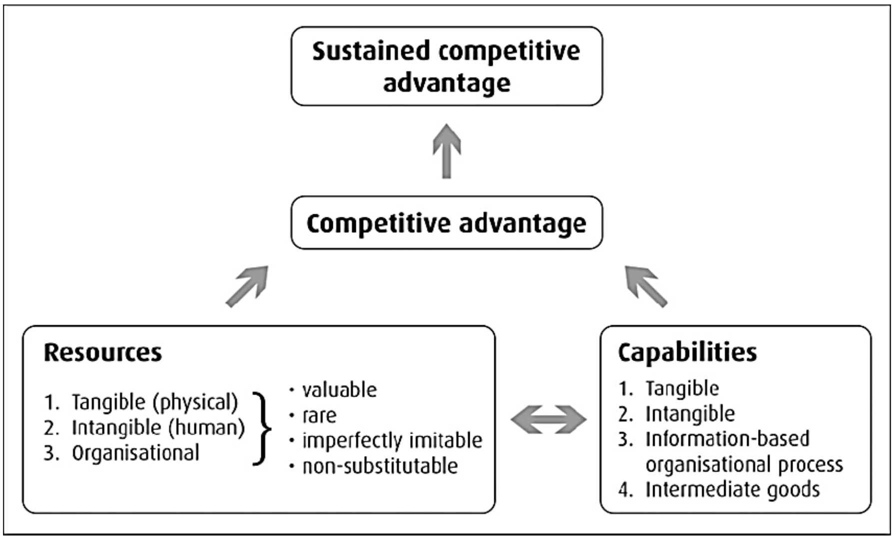

Figure 7: Resource-Based View
Source: Prause et al. (2012)

2.2.2.2 Blockchain as a Strategic Capability

Blockchain offers strategic capabilities that reconfigure supply chain management, making it more traceable, secure, and transparent, key expectations in the era of responsible consumption. Unlike traditional databases, Ahmed and McCarthy (2021) state that blockchain enables real-time verification of transactions across suppliers, helping fashion companies to track garments from raw material origin to the point of sale. These features become valuable intangible assets supporting ethical branding, reducing reputational risk, and supporting proactive compliance with ESG frameworks. Smart contracts, a core component of blockchain, are programmable, self-executing codes that enforce pre-defined conditions, reducing the need for intermediaries and human oversight (IBM, 2025). This automation can lower operational costs, facilitate ESG data collection, and enable real-time compliance monitoring. These are not generic digital tools, they require firm-specific configurations, creating unique operational pathways that qualify as complex and inimitable capabilities under RBV. Firms such as Adidas and Hugo Boss have begun piloting blockchain to authenticate products, sustainability reports, and automate due diligence, all of which provide strategic control over reputational assets and sustainability metrics (Jenkins, 2023).

The adoption of blockchain technology in supply chains largely depends on internal readiness, including organizational infrastructure, technical literacy, and change management capabilities. The RBV framework argues that not merely possession, but the effective utilization of resources yields competitive advantage. Organizational preparedness to adopt blockchain includes integrating legacy systems, training personnel in decentralized data management, and establishing new governance structures for interdepartmental and inter-organizational collaboration (Marcelletti, 2023). Larger fashion conglomerates like LVMH or Kering have the capital and human resources to lead blockchain experimentation and deployment (McKinsey & Company, 2023). In contrast, Susitha et al. (2024) state that Small and Medium-sized Enterprises (SMEs), which dominate the fashion sector's downstream supply chain, often lack the IT infrastructure, change agility, and strategic foresight to experiment with blockchain applications. Bag et al. (2023) point out that this readiness gap delays adoption and exacerbates competitive asymmetry, reinforcing the dominance of technologically advanced firms. For example, Puma has launched a pilot blockchain initiative focusing on material traceability, aiming to authenticate sustainability claims and reduce supplier opacity (PUMA, 2024). Such case examples show that blockchain is a technological solution and a strategic process innovation that redefines internal capabilities and external positioning. Partnerships also play a key role; collaboration with tech providers such as IBM or SAP allows firms to outsource blockchain expertise while focusing on strategic integration (IBM, 2025).

2.2.2.3 Gaining Competitive Advantage via Blockchain

Blockchain adoption can yield tangible competitive advantages. Firstly, it fosters consumer trust by enabling the verification of sustainability claims. Consumers, especially Gen Z and Millennials, are increasingly aware of greenwashing and demand digital assurance of product provenance (Mabkhot, 2024). Second, Manifest Climate (2025) reports that blockchain enables faster and more reliable ESG reporting, reducing the compliance burden associated with frameworks such as GRI, CSRD, and ISSB. Automated audit trails and immutable ESG metrics facilitate investor confidence and regulatory alignment. Third, blockchain helps mitigate fraud, counterfeiting, and labor exploitation, which have long plagued the fashion industry. Firms implementing blockchain can streamline audit operations, cut compliance costs, and reduce the need for costly third-party verifications (Fahdil et al., 2024).

2.2.3 Integrating Institutional Theory and RBV

The combination of Institutional Theory and the Resource-Based View (RBV) can be deemed as a well-established and strong method of analyzing blockchain adoption in fashion supply chains. Institutional Theory explained by DiMaggio and Powell (1983) explains that the firms face coercive, mimetic and normative forces which push the firms into embracing technologies that will help them increase transparency. In complement, RBV- as portrayed by Barney (1991) keeps on saying that it is the inner resources i.e. the technological preparedness and strategic potential that dictate the firm ability to effectively answer such pressures. Together, these theoretical lenses can explain the reasons behind the integration of a blockchain, as well as the resource-based circumstances when its implementation is possible and can be seen as a necessary dual-perspective analytical toolset to evaluate the results of actual implementations in such a way. Institutional Theory answers the questions of the coercive, normative, and mimetic pressures that influence the determinants of legitimacy imperatives as the why of adopting blockchain. The regulatory expectations are applied by the coercive pressures, including the EU Corporate Sustainability Due Diligence Directive and the UK Modern Slavery Act. Normative pressures arise out of industry norms (like the Global Reporting Initiative and the International Sustainability Standards Board), on the one hand, and the expectations of external stakeholders, on the other hand. Mimetic pressures occur when companies follow the strategies of other firms in order to be competitive. These outside expectations are more particularly relevant to the fashion industry, a sector heavily scrutinized due to various labor abuses, environmental degradation, and the lack of transparency in supply chains (Tandon et al., 2025).

RBV, in turn, describes how: through the mobilization of internal resources the effective implementation of blockchain is facilitated, which contributes to the competitive advantage because of elevated levels of transparency and operational efficiency (Barney, 1991). Sterling firms with high digital maturity and dynamic capabilities have better abilities to pursue the successful adoption of blockchain, thus, increasing traceability, reducing fraud, and strengthening ESG reporting. Conversely, firms lacking these internal enablers face barriers despite facing the same external pressures. Therefore, dual-theory integration reflects both constraints and enablers. External legitimacy pressures push firms toward adopting blockchain; internal resources determine the pace and efficacy of adoption (Bag et al., 2023). This synergy is beneficial in contexts like fashion where stakeholder demands (consumers, investors, regulators) are escalating, but fragmented supply chains and technological readiness limit implementation. The integrated model can thus guide firms in identifying their adoption gaps whether they stem from insufficient legitimacy recognition or weak internal resources and shape strategies accordingly. It supports academic inquiry by connecting macro-level institutional drivers with firm-level strategic responses.

2.3 Conceptual Framework

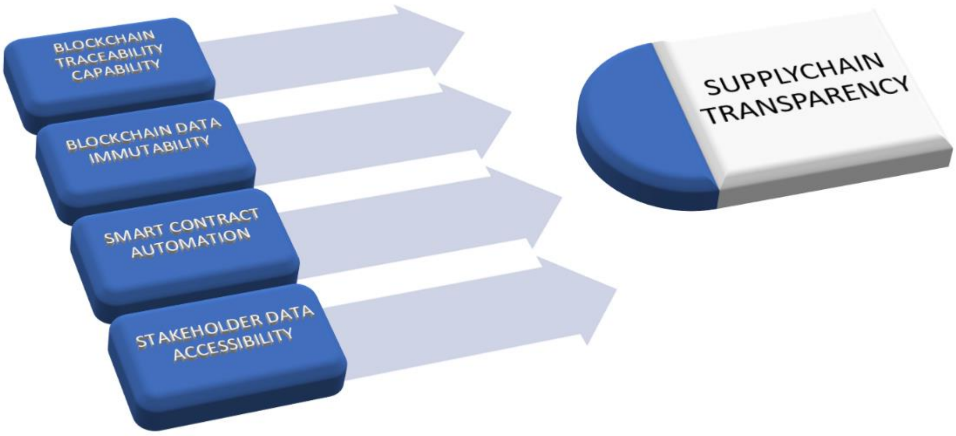

Figure 8: Conceptual Framework
Source: Author's work

In the present investigation, a conceptual framework can be seen as a visual and analytical tool explaining the causal relationship between blockchain capacities and transparency in fashion supply chains. The framework synthesizes institutional theory and the resource-based view (RBV) based on its explanations of the need for external legitimacy and the mobilization of internal resources. Its main goal is to show how far strategically implemented blockchain solutions can increase traceability, strengthen accountability, and enhance data visibility in fragmented fashion supply chains, and at the same time meet both Sustainable Development Goal 12 (Responsible Consumption and Production) as well as Environmental, Social, and Governance (ESG) guidelines.

As the framework is shown diagrammatically, it comprises four independent variables (IVs) that are measured individually but go towards building a cutting edge to the dependent variable (DV): supply chain transparency. These IVs are Blockchain Traceability Capability, Blockchain Data Immutability, Smart Contract Automation, and Stakeholder Data Accessibility. Every variable has an operational mechanism (discrete), achievable because of the blockchain, and they all complement the larger goal of transparent, ethical, and sustainable supply chains.

2.4 Blockchain Technology Overview and Relevance to Supply Chain Transparency

2.4.1 Introduction to Blockchain Technology

Blockchain is a tamper-proof, decentralized, digital record or list of transactions that permits recording, verification and storing transactions over networks of computer systems or nodes without needing a centralized authority (Dong et al., 2023). Its structure also ensures that it can never be changed after inserting data into the blockchain, thus providing much transparency and trust to systems that need verifiable and trackable records (Casino et al., 2019). Initially developed by Nakamoto (2008) to support the cryptocurrency Bitcoin, blockchain has since evolved into a very adventurous technology with many uses that apply far beyond digital currencies. Over the past years, the technology has found its way to enterprise landscapes, especially where it is highly essential to have security, provenance, and decentralized control. Blockchain is being implemented in banking, insurance, healthcare, and logistics to deal with endemic issues such as information asymmetry, data tampering, and multisilos (Kshetri, 2018). At the same time, the manufacturing and distribution industry has started using blockchain to keep complicated ecosystems of supply chains that require traceability and situational coordination.

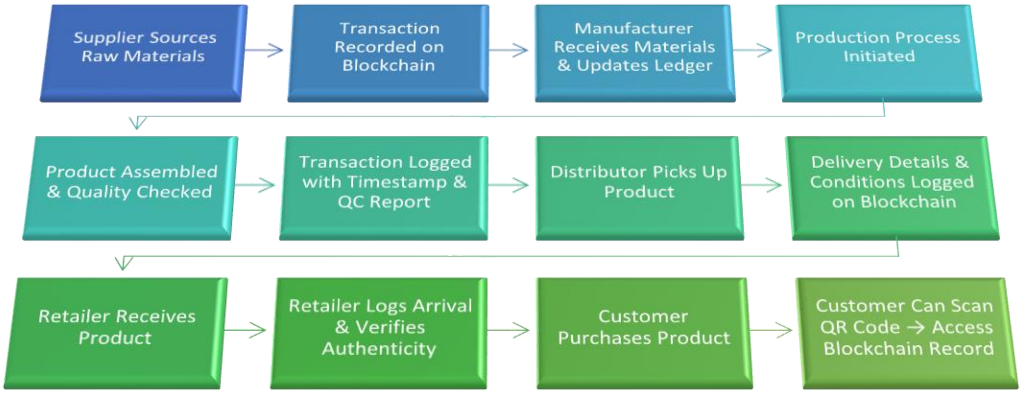

Figure 9: Blockchain Adoption in Supply Chain
Source: Author's work

Several practical examples indicate how blockchains are becoming more widespread in contemporary supply chains, such as IBM and Kaya & Kato, which use blockchain platforms to track sustainably sourced fabrics, or the Aura Blockchain Consortium, which, comprising LVMH, Prada, and Cartier, was established to verify product provenance. Simultaneously, Everledger helps brands to store data on the ethical sourcing of luxury items. However, adoption is still defined by high implementation costs, especially to small and medium-sized businesses, and the challenge of matching blockchain architectures to legacy enterprise resource planning. These barriers are multiplied by the lack of digital skills among upstream suppliers and the heterogeneity of various jurisdictions, making developing common standards more challenging. All these constraints ultimately curtail the actualization of the potential of blockchain as a means to foster transparency over the supply chain across the globe.

2.4.2 Evolution of Blockchain from Cryptocurrency to Enterprise Tool

Blockchain technology has evolved significantly since its inception, transitioning from its origins in cryptocurrency to a sophisticated enterprise-level tool. The first generation of blockchain was marked by the introduction of Bitcoin, which used a decentralized peer-to-peer network to facilitate digital currency transactions without intermediaries (Nakamoto, 2008). Bitcoin's use case demonstrated the viability of decentralized ledgers in eliminating the need for trust in third-party systems.

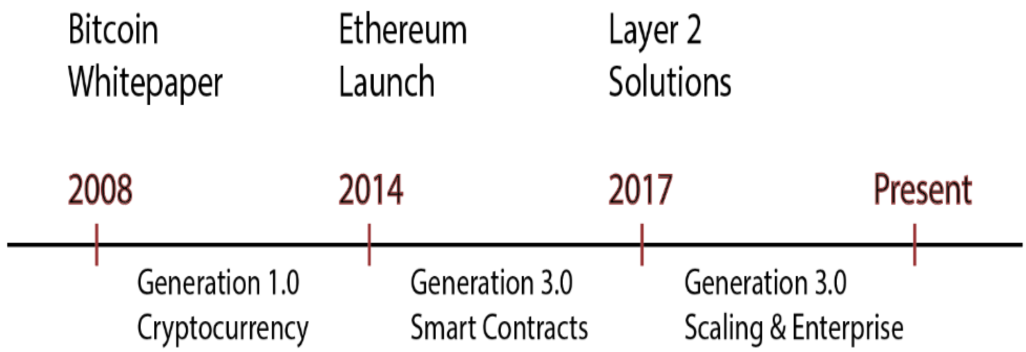

Figure 10: Evolution of Blockchain Technology
Source: (Singh, 2025)

Blockchain technology has seen significant development since its introduction. The second generation, which was introduced with the deployment of Ethereum in 2015, brought on smart contracts, programmable, automatic contracts that do not require intermediaries (Kaur et al., 2022). This was an improvement on blockchain that made it applicable in areas other than cryptocurrency by enabling decentralized apps (dApps). However, in the real world, many public networks' instability and scalability issues have caused a lack of topical adoption in various industries. Despite these shortcomings, the power of Ethereum was demonstrated most dramatically in the world of logistics through Provenance, which empowered the supply chain tracing of ethical apparel brands on the immutable ledger and resolved the growing need for transparency among customers regarding the fashion industry.

A third generation or the next generation of blockchain takes the scalability, interoperability, and privacy even further by implementing permissioned and privately accessible networks. Hyperledger Fabric, Quorum, and Corda are examples of enterprise-grade platforms that offer commercial solutions to a specific problem (Morkunas et al., 2019). Unlike the public chains, these blockchains only allow access by authorized parties, an imperative feature in industrial practices where regulatory compliance and protecting trade secrets are critical. Now shelved, the TradeLens platform of IBM and Maersk showed enterprise blockchain at its best and worst. The platform increased efficiency and trust due to digitizing international trade documentation. Still, they were unsuccessful in scaling due to limited stakeholder adoption and ongoing competition against existing methods, which shows that technological innovation is not the assurance of utilization. In the supply chain field, blockchain is used more frequently for counterfeit protection, ethical procurement, and product authenticity, especially in more sustainability-focused industries (Saberi et al., 2019; Treiblmaier, 2019). However, ongoing criticisms are the viability of energy consumption (in proof-of-work systems), the difficulty of incorporation, and the uncertainty of regulatory enforcement. The shift toward permissioned networks marks a technical necessity and a realignment of strategic priorities to meet enterprise users' governance and security requirements. In fashion supply chains, this evolution enables brands like LVMH and Puma to utilize private blockchains for verifiable sourcing, transparent labor conditions, and compliance-driven reporting without exposing sensitive supplier data.

2.4.3 Technical Components of Blockchain

Blockchain technology comprises several foundational components enabling decentralized, transparent, and tamper-proof data systems. This makes it especially valuable for applications in complex supply chains such as fashion (See Fig 7). Understanding the technical building blocks is essential for evaluating their potential to address longstanding traceability, auditability, and trust issues (Centobelli et al., 2022).

2.4.3.1 Distributed Ledger Technology (DLT)

Blockchain is built on the mechanism of Distributed Ledger Technology (DLT). DLT allows peers to have a synchronized view of transactions and data entries in terms of a time-stamped database synchronized to correlate with a time-stamped database distributed across a peer-to-peer network. This architecture dramatically reduces the chances of compromising the data or one-directional updates (Farahani et al., 2021). Vadgama et al. (2019) state that, similar to the fashion industry in highly fragmented supply chains, DLT can help develop trust and consistency since each involved stakeholder, i.e., cotton farmers to boss-level retailers, retrieves an identical version of truth. In a fashion context, DLT increases traceability by offering shared visibility into the sourcing, processing, and distribution of information, thus making it easy to verify ethical practices.

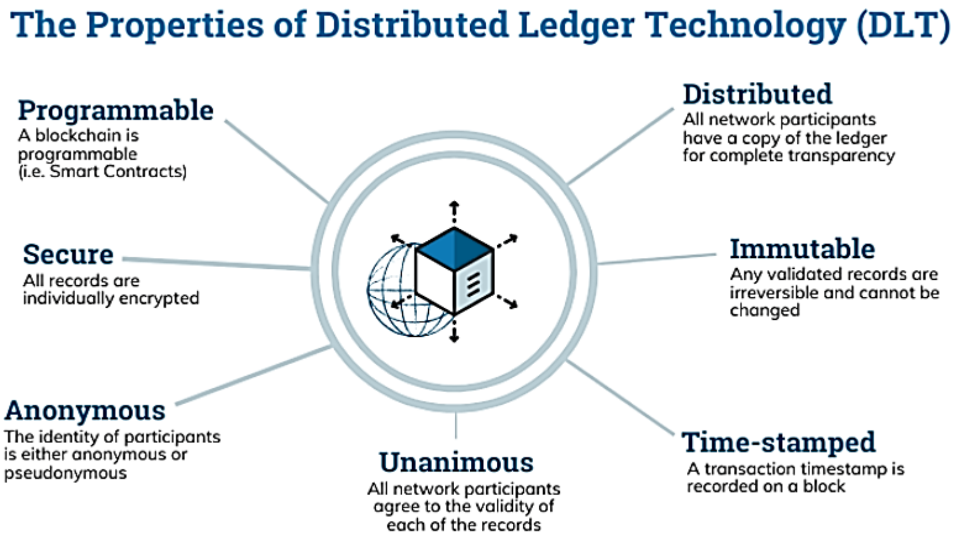

Figure 11: The properties of distributed ledger technology
Source: Dey et al. (2022)

2.4.3.2 Smart Contracts

Smart contracts are programmable rules encoded into blockchain and can be conceptualized as the computer implementation of clauses within a contract. Smart contracts dissociate dependency on brokers and permit computerizing the checks to execute agreements, liberation of payments, and quality surveillance. Hasan et al. (2019) illustrate that in fashion supply chains, a smart contract only releases payment once GPS coordinates show the shipment to a certified warehouse, thereby enhancing operational efficiency and enforcing club within the digital fabric of the exchange. In fashion, smart contracts will ensure that the sustainable materials are purchased conditionally and uphold fair labor terms without requiring manual supervision.

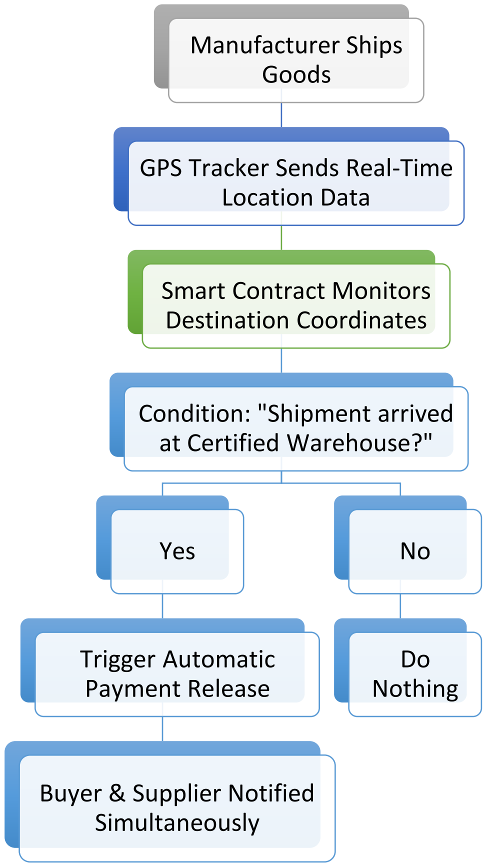

Figure 12: Concept Diagram: Smart Contract in a Fashion Supply Chain
Source: Author's work

2.4.3.3 Consensus Mechanisms

Consensus mechanisms are a fundamental cornerstone to the support of integrity and maintenance of the agreement within blockchain ecosystems without the existence of centralization. This constellation consists of a heterogeneous set of protocols with different performance characteristics. The consensus scheme utilized in Bitcoin, Proof of Work (PoW), protects security through computational puzzles, but at a high cost in terms of energy consumption. Zhang and Chan (2020) prove that Proof of Stake (PoS) eliminates energy usage to find a suitable validation resource, and it transfers the validation to the possession of tokens, thus reaching a consensus without cost-hungry mining. According to Al Salih (2024), Practical Byzantine Fault Tolerance (PBFT) is an algorithm that is fast in consensus in environments where permission is provided, e.g. Hyperledger, which is considered to fit the needs of the fashion supply networks perfectly. The reduced latency and resiliency to node failure that is a property of PBFT make PBFT-based systems appealing in high-throughput applications such as fast fashion logistics, where high throughput means thousands of product traceability checks can be performed in real-time during the peak seasons (Xiao et al., 2020).

2.4.3.4 Immutability and Cryptographic Hashing

Blockchain credibility is associated with the impossibility of altering data once added to the blockchain, making manipulation unreadable. The security of this property is achieved through cryptographic hashing: the transaction data of one block is combined with a unique hash of the previous block, thus forming an unforgivable chain of entries. Blockchain technology extensively depends on the functions of cryptographic hash to operate. The fundamental principle driving integrity and security in blockchain is the consistent chaining of blocks with the help of cryptographic hashing (Kuznetsov *et al.*, 2023).

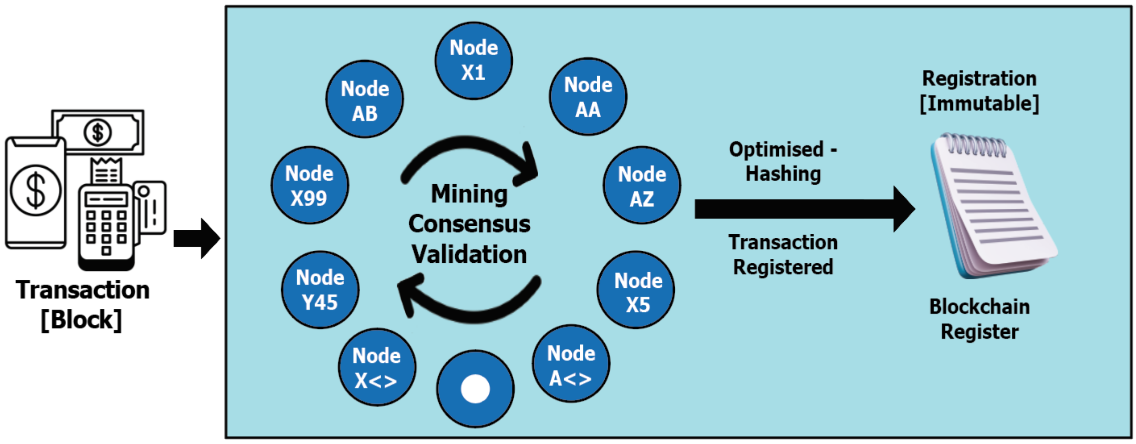

Figure 13: Blockchain Hashing Framework
Source: (Sinha and Mukhopadhyay, 2024)

Saberi et al. (2019) highlight the crucial role of this mechanism in ensuring the validity of such claims as carbon footprint Disclosure and certification of labor processes in a fashion supply chain, discouraging post-hoc judgments and correctly constructed reporting. Immutability helps firms fight any greenwashing accusations and prove sustainability statements.

2.4.3.5 Permissioned vs Public Blockchains

Blockchain infrastructures are typically divided into permissioned (exclusively accessible) or publicly available. Though public networks present the highest levels of transparency, they could be inappropriate for proprietary or sensitive information in the industry. Permitted frameworks, including Hyperledger and Quorum register, offer permitted access, faster transaction time and comply with data-privacy laws, making them especially suitable to fashion supply chains that need to distribute visibility throughout tiers Treiblmaier (2019) selectively. Such programmable structures will allow confidential publication of contractual agreements between relevant involved parties and an end-to-end trail simultaneously. As a result, leading fashion brands often choose permissioned networks at similar positions to strike a balance between consumers' transparency and suppliers' privacy.

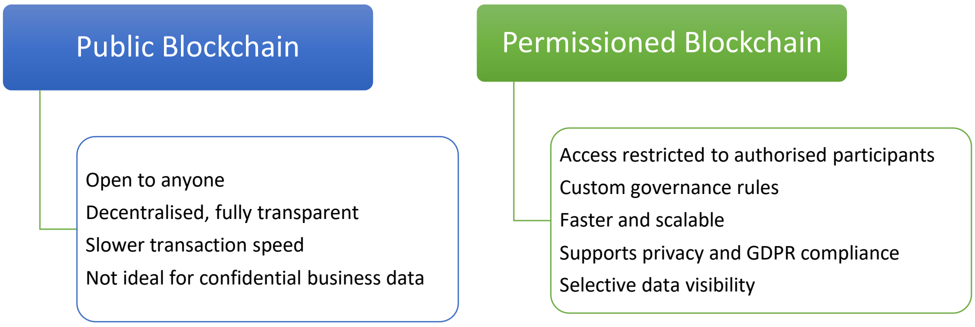

Figure 14: Public vs. Permissioned Blockchain in Fashion Supply Chains
Source: Author's work

2.4.3.5 Real-World Tools and Platforms

Over the last few years, organizations with a supply chain focus have proposed a package of blockchain platforms that should facilitate adoption in the fashion sector. According to Gaur et al. (2020), one of the initial steps toward developing decentralized applications was the development of Ethereum's capability regarding smart contracts. IBM Blockchain is based on the Hyperledger Fabric framework, delivering modular and scalable solutions to various industries, including textiles. In contrast, VeChain focuses more on supply chain traceability and has partnered with retailers to build blockchain-based tags that can prove the provenance and authenticity of individual products (Jenkins, 2023), with H&M and Baby ghost being among them. All these implementations describe how blockchain is transitioning out of the theoretical stage and into practical application, and how it has become a higher priority in logistics in the fashion industry. Well-designed, the technical elements of the blockchain provide a reliable foundation for enhanced visibility, responsibility, and automation of the fashion supply chain. Amid the ramped-up complexity of sourcing and the growth in regulatory oversight, a delicate knowledge of the fundamental technologies is essential to successful adoption and congruence with sustainability value systems.

2.4.3.6 Data Integrity and Trust

One of the most popular qualities of blockchain is the possibility of data integrity due to tamper-proof records. After recording any transaction, Politou et al. (2019) maintain, validation by consensus makes it impossible to alter, effectively limiting prospects of retroactive falsification, an element of utmost importance to the fashion world, where allegations concerning organic origins or fair labor practices are often under intense scrutiny by consumers and regulators alike. Gariba et al. (2024) elucidate further that ledgers on blockchain networks hinder the likelihood of fraudulent transactions and increase the stakeholder confidence in the disclosure of sustainability performance, owing to cryptographically anchoring and timestamping every supply chain event. A recent example lies in the Aura Blockchain Consortium developed by VMH, which allows users to view the origin and authenticity of luxury items, reduces counterfeit activity, and strengthens the brands as their credibility rises (Aura Blockchain Consortium, 2024).

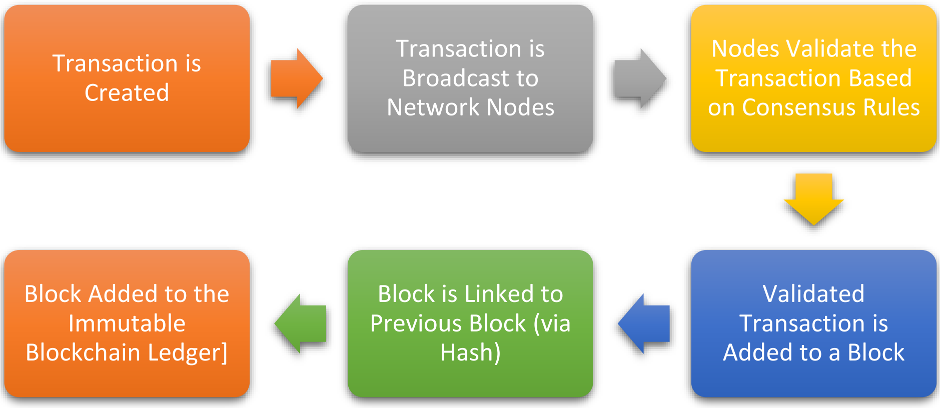

Figure 15: Data Integrity and Trust in Blockchain
Source: Author's work

2.4.3.7 Decentralization and Disintermediation

Blockchain also allows the intermediary to be abandoned due to the validation of transactions, which has been tectonic in the past due to delays, overrunning costs, obscurity, and corruption (Chang et al., 2020). As Hammi et al. (2018) highlighted, decentralization shifts the verification power back to a distributed network, thus building a common source of trust. This attribute is particularly significant in the fashion supply chain system, where the growers, manufacturers, logistics providers, and retailers often work in a siloed system, rarely with much transparency. Blockchain replaces contract enforcement with collaborative trust by enabling all parties, via consent, to share a common ledger in real-time, an example being the use of blockchain to promote transparency in the diamond and luxury-goods supply chain by Everledger (Everledger, 2023).

2.4.3.8 Auditability and Regulatory Compliance

The immutability and timestamping features of blockchain provide a reliable source of regulatory compliance and audit. The distributed ledger system creates real-time, automated audit trails that do not need to be latent and can be interrogated by the regulators and external auditors, minimizing the cost of audit and technical complexities (Gallego, 2025). Saxena et al. (2022) note that blockchain facilitates a reduced price and more efficient environmental, social, and governance (ESG) reporting by including information or data on sustainability at the source. This native auditability, combined with new regulations like the EU Corporate Sustainability Reporting Directive (CSRD) and International Sustainability Standards Board (ISSB) that mandate verifiable, digital disclosure methods, further supports an affinity between blockchain solutions and new policy frameworks.

2.4.3.9 Automation of Operations

Blockchain also allows the automation of key operational processes by using smart contracts, protocols that self-execute and are coded with specified preconditions. As shown by Ullah and Chowdhury (2025), these types of smart contracts are capable of performing actions, e.g., approving payments, issuing notifications, or submitting documents, and thus reduce error rates and speed up workflows without any human input. As an example, Hasan et al. (2019) show a smart contract that will automatically authorize a shipment and initiate payment after receiving information about the arrival of a product with the help of GPS devices. Such mechanization limits manual reconciliation and reduces third-party supervision, simplifying the fashion industry's logistics and finance management chain. Automation increases efficiency and the application of compliance rules transparently and consistently across all the partners involved in the supply chain. Conclusively, blockchain technology is a powerful solution to a set of challenges that have affected fashion supply chains over time and enhances data integrity, decentralize trust, automate the process and achieve complete traceability with very high similarities to the rising priorities in the industry associated with trends in sustainability, compliance and efficiency of operations.

2.4.4 Relevance to Fashion Supply Chains

The fashion supply chains are highly fragmented and opaque in information, with a typical chain entailing vast numbers of subcontractors, raw materials suppliers, and manufacturers spread across many jurisdictions. McKinsey & Company (2022) points out that the average fashion product goes through different hands and countries until it reaches its final customer, thus hindering control. This complexity increases the possibilities of unethical labor standards, environmental non-compliance, and the creation of fraudulent sustainability descriptors, as brands rarely have a real-time view beyond Tier 1 suppliers. These dynamics are exacerbated by the fast-fashion paradigm: fast production-driven companies such as Zara and H&M require more intense cycles, which provide little time to hold rigorous checks of the whole supply chain. In this scenario, the transparency of the supply chain and agile, accurate monitoring becomes necessary.

The classic identifiers, such as barcodes, spreadsheets, etc., cannot meet the needed velocity and surety. As a result, blockchain has materialized an opening that is being increasingly filled. A decentralized, tamper-resistant ledger provided by technology offers a stable model for collecting, storing, and sharing supply chain data throughout all production levels. For example, manufacturers can utilize smart-contract protocols and blockchains to document sourcing of raw material, use of water, and workers, providing real-time access to approved parties across the chain. This transparency enables the verification of wages and traceability of origin and carbon-footprint assessments to be hidden before. In addition, the capability of blockchain to prevent greenwashing is recognized. Wang and Walker (2023) state that consumers place higher credence in the sustainability evidence-backed with immutable recordings than self-reported information.

The increased importance of blockchain in fashion is already confirmed through real-life applications. Started in 2021, the Aura Blockchain Consortium (2024), built by LVMH, Prada, and Cartier, includes the issuance of digital product passports that track the raw materials as they move to retail, which provides greater transparency, increases consumer confidence, and reduces the possibility of counterfeits. Another recent interaction with Kaya & Kato, a sustainable German textile company, by IBM in 2020, also applies blockchain to document inputs used in production and certify compliance with ecological principles, further consolidating the brand's credibility and assisting in complying with ESG.

Oguntegbe et al. (2023) emphasize that blockchain can help with brand reputation management in modern times, as environmental and social performance play a significant role. Blockchain can serve as a differentiating strategic asset and a technological solution because it allows sustainability to be demonstrated based on verifiable actions instead of promotional discourse. However, various barriers also exist, such as non-standardization, increased cost of implementation and interoperability challenges with legacy systems that deter further deployment (Prewett et al. 2020). The limitations would require continuous studies and rounds of improvements before blockchain technology could live up to its expectations in the fashion industry.

2.5 Blockchain Challenges in Fashion Supply Chains

2.5.1 Technological Barriers

2.5.1.1 Scalability Issues

Scalability remains one of the most prominent limitations to blockchain's widespread use in fashion supply chains. Within a blockchain system, issues pertaining to scalability have been classified into three diverse categories which include throughput, storage, and cost (Kohad, Kumar and Ambhaikar, 2020). The said categories are interdependent for instance, in several cases, transactions within blockchain are confronted with latency issues arising from the block's limited size. Appending a block to the chain would warrant the need to resolve an intricate mathematical conundrum, further necessitating time and computational efforts. There is no scope to minimize the time consumed for block generation, which impacts the throughput (Kumar *et al.*, 2019). Moreover, a cost (termed as gas) is also supposed to be paid by the requester, for every transaction. From a blockchain perspective, the measurement of throughput is done based on pace of block generation per second. Storage is yet another factor that impacts scalability. With blockchain sizes increasing on a day-to-day basis, it requires a robust and efficient storage system (Alghamdi, Khalid and Javaid, 2024).

Furthermore, traditional blockchain platforms like Ethereum face significant transaction throughput limitations, directly conflicting with global fashion logistics' high-volume, time-sensitive nature (O'Dair, M., 2018). For instance, Bitget (2025) claims that Ethereum can process approximately 15–30 transactions per second, considerably slower than conventional enterprise systems like Visa, which can handle over 1,700 transactions per second. This latency makes it challenging to integrate blockchain in fast-paced, real-time supply chain environments where rapid data processing is critical. The decentralized nature of blockchain, while offering tamper-resistance and trust, often sacrifices processing speed and energy efficiency, a phenomenon known as the "blockchain trilemma" (Scalability, Security, Decentralization). As Treiblmaier (2019) highlights, this trade-off raises operational questions about whether blockchain is suited to fast fashion's low-margin, high-velocity models. To address this, newer platforms are exploring Layer 2 solutions and consensus mechanisms like Proof-of-Stake (PoS), but these remain nascent and lack widespread implementation.

2.5.1.2 Integration with Legacy Systems

A further impediment is integrating blockchain platforms with existing Enterprise Resource Planning (ERP) systems, such as SAP and Oracle, which are not inherently designed to accommodate decentralized data structures. Blockchain systems often operate on different data protocols and frameworks, making interoperability a major technical hurdle (Saberi et al., 2019). The fashion industry's heavy reliance on fragmented legacy systems exacerbates this challenge, especially among fast fashion firms that continue to use proprietary, outdated databases resistant to external synchronization. Moreover, Loots (2023) integrating blockchain often demands substantial system reconfiguration, IT consultancy, and training, creating additional costs and labor-intensive obligations for companies. Jenkins (2023) has shown that fashion companies with centralized data infrastructures express high resistance due to the fear of disruption and limited internal capabilities. As a result, blockchain implementations are frequently siloed or piloted in isolated functions without systemic integration across supply chain layers, thereby diluting potential impact.

2.5.1.3 Energy Consumption and Environmental Costs

The ethical paradox of employing energy-intensive technology to solve sustainability issues in fashion cannot be overlooked. Proof-of-Work (PoW) consensus mechanisms, used by early blockchain systems like Bitcoin, require immense computational power (Lasla et al., 2022). In 2023, Bajra et al. (2024) maintain that Bitcoin's annual energy consumption exceeded 85 TWh, comparable to the energy use of small countries. This contradicts the fashion industry's goals to reduce carbon emissions and promote circularity. Although Bitget (2025) reports that Proof-of-Stake (PoS) models significantly reduce energy usage, Ethereum's 2022 shift to PoS cut its energy consumption by over 99.9%, most fashion-related blockchain pilots still operate on private, permissioned blockchains where sustainability benchmarks remain vague. However, even with more energy-efficient models, the overall lifecycle of blockchain infrastructure, including hardware demands, remains insufficiently explored in environmental assessments. Thus, while blockchain holds promises for enhancing transparency and ethical sourcing, these technical and ecological barriers illustrate the need for cautious, context-specific deployment. Without addressing scalability, integration, and sustainability concerns, blockchain risks become a symbolic gesture rather than a practical tool for transformation.

2.5.2 Organizational Challenges

2.5.2.1 Resource Constraints in SMEs

SMEs' main organizational limitations regarding blockchain technology application include resource scarcity. The availability of financial capital, IT infrastructure, and skilled workers is restricted; therefore, many SMEs cannot maintain the investment in digital transformation. To MNCs, the ability to experiment and assimilate technological unknowns is an option with ready access to fixed resources; to SMEs, such outlays are unaffordable, due to thin margins (Bag et al., 2023). This disequilibrium creates a digital distinction where the ability to be innovative is focused on mega Western companies, subsequently denying lower-end suppliers the possibility of joining transparent ecosystems. Further, Naradda Gamage et al. (2020) find that Asia and Africa, where textile-based SMEs prevail, face systematic limitations mostly in non-stable internet services, limited cloud capacity and elimination of corporate IT departments. Therefore, the use of blockchain appears to be a technological issue and structural imbalance in international value chains.

2.5.2.2 Digital Maturity and Change Management

Low levels of digital maturity present another obstacle. Upstream supply chain actors, including raw material suppliers and manufacturing units, often lack exposure to blockchain applications or broader digital technologies (Calvão and Archer, 2021). This resistance is often rooted in fears of data surveillance, loss of autonomy, or exposure of unethical practices (Wamba and Queiroz, 2020). Moreover, change management initiatives fail to align governance structures and stakeholder expectations. A pertinent example can be found in Bangladesh's garment sector, where Miraz et al. (2018) report that blockchain pilot schemes have faced opposition from suppliers reluctant to disclose wage structures and sourcing practices. This signals a deeper issue of accountability avoidance and power asymmetries between buyers and producers. Training and capacity-building efforts are also limited and insufficiently targeted. Without ongoing education on blockchain's practical benefits—such as enhanced traceability, quicker ESG compliance, and reduced greenwashing risks, stakeholders are unlikely to see the value in adoption (Yahaya, 2025). This misalignment further entrenches the status quo and slows down systemic innovation.

2.5.2.3 Unclear ROI and Risk Aversion

The return on investment (ROI) for blockchain systems in fashion remains ambiguous, particularly in the short term. Unlike ERP or inventory management systems that produce immediate cost savings, blockchain's payoff is more diffuse; it manifests in improved trust, better compliance, and reputational gains (Boppana, 2024). These are harder to quantify and justify in corporate budgeting exercises, especially during economic downturns or periods of tight liquidity. Firms often perceive blockchain as an experimental, high-risk initiative rather than a strategic imperative (Treiblmaier, 2019). As a result, many organizations choose to prioritize other technologies with more visible impact metrics. This uncertainty fosters a culture of risk aversion. Although scholars and practitioners have a growing interest in blockchain technology, many fashion businesses (particularly in the procurement, compliance, and sustainability departments) are still hesitant to support blockchain, due to an ambiguous path towards a healthy return on the investment (ROI). Most often, managers are subject to short-term performance measures, and the project duration of blockchain initiatives is often not aligned with traditional organization periods (Saberi et al., 2019). These efficient concerns and the relative lack of empirical case studies showing demonstrable efficiencies, cost savings, or environmental, social, and governance (ESG) compliance bolster an existing wait-and-see attitude.

One of the most noticeable gaps in modern literature is the lack of industry-specific case studies that measure and summarize improvement in efficiency, cost reduction, or increased ESG. Most existing research focuses on the potential benefits of blockchain but does not ask questions about the actual performance of the implemented systems or the associated cost-benefit calculations, especially on the side of small and medium-sized enterprises (SMEs). To this end, decision-makers still do not have the empirical evidence to justify internal business cases of adoption. Along with them is organizational preparedness, which remains a rigid hindrance. Research often delineates this construct broadly, but Mohammad and Vargas (2022) question the barriers to using blockchain-based tools, including a lack of digital literacy, fear of disrupting the workflow, or an absence of talent in blockchains in-house. These are essential elements, as without direct funding, technical support, and government stimuli, SMEs will hardly embrace blockchain tools, regardless of their technological level. Given that, without solving these internal, structural issues and producing sector-specific performance data, the transformative potential of blockchain in fashion supply chains will be a dream, but not a reality.

2.5.3 Regulatory and Ethical Concerns

While blockchain technology offers enhanced transparency and accountability in fashion supply chains, its deployment raises regulatory and ethical concerns, particularly in contexts governed by stringent data protection laws and fragmented cross-border jurisdictions. One of the most contentious regulatory dilemmas lies in the contradiction between blockchain's immutability and data privacy requirements. Blockchain is inherently designed to be tamper-proof, meaning that once data is recorded, it cannot be altered or deleted (Thilakavathy et al., 2023). However, this conflicts with the European Union's General Data Protection Regulation (GDPR), especially Article 17, the "Right to be Forgotten," which mandates that individuals should be able to request the deletion of personal data (EU GDPR, 2018). For example, storing wage or employment data of factory workers on an immutable ledger without consent raises substantial ethical and legal risks. Even though advanced cryptographic techniques like zero-knowledge proofs have been proposed as solutions, their integration into live systems remains nascent and technically complex (Bodie, 2022). Zero-knowledge proof enables verification of compliance or data accuracy without revealing the underlying sensitive information, thus protecting privacy while ensuring transparency.

Cross-border governance represents another significant regulatory hurdle, especially since fashion supply chains extend across jurisdictions with differing legal frameworks. For instance, a blockchain platform designed in the EU may involve manufacturing hubs in Bangladesh or Vietnam, where data residency laws are either less stringent or non-existent. This misalignment creates ambiguity over data transfer rights, ownership, and access. Recent efforts by the European Commission to harmonize digital governance through mechanisms such as the Digital Product Passport (DPP) still do not offer clear guidance on multi-country operations (EPRS, 2024). Blockchain projects risk violating sovereign data policies or leaving critical compliance gaps without a common global legal infrastructure.

The absence of blockchain-specific regulatory standards for the textile and apparel sector is equally problematic. Unlike industries such as finance or healthcare, which benefit from well-defined blockchain auditing and compliance protocols, the fashion industry lacks sectoral benchmarks to govern ethical blockchain usage (Altawil, 2024). For example, while the Corporate Sustainability Reporting Directive (CSRD) and International Sustainability Standards Board (ISSB) offer broad ESG disclosure guidelines, they do not provide technical pathways for blockchain integration (Hajiyev, 2024). Consequently, firms often rely on ad hoc or proprietary systems that can lead to data silos or non-standardized reporting, undermining the very transparency blockchain aims to achieve. This regulatory vacuum further complicates adopting traceability initiatives like the Digital Product Passport, which will become mandatory in the EU by 2027 for the textile sector (EPRS, 2024).

2.5.4 Stakeholder Misalignment and Trust Issues

Stakeholder misalignment is a persistent issue in blockchain adoption across fashion supply chains, mainly due to the' fragmented and unequal nature of global production networks (Marques et al., 2025). The fashion supply chain comprises entities with divergent technological capacities, operational goals, and risk appetites. While luxury brands or major fast fashion retailers may possess the digital readiness and capital to deploy blockchain, Joysoyal et al. (2024) claim that upstream suppliers in regions like Bangladesh often lack the infrastructure or training to participate effectively. This misalignment hampers end-to-end transparency and risks reinforcing digital divides. Additionally, power asymmetries between lead firms and smaller suppliers exacerbate mistrust. Ahme and McCarthy (2023) explain that suppliers may view blockchain-enabled traceability as a surveillance mechanism rather than a collaborative tool.

Moreover, trust deficits extend to blockchain administrators. In permissioned systems, the role of third-party validators or platform providers becomes contentious. Smaller stakeholders remain reluctant to engage without transparent governance structures and equitable data-sharing policies (Gariba et al., 2024). Trust is further eroded when brands prioritize rapid product cycles and profit margins over long-term investments in ESG-aligned innovation. The short-termism prevalent in market-led strategies often sidelines blockchain as an expendable innovation rather than a core strategic asset (Kaur et al., 2022).

2.6 Sustainability Challenges and the Imperative for Blockchain Integration in Fashion Supply Chains

2.6.1 Environmental Degradation in Fashion Supply Chains

The fashion industry's environmental footprint is widely acknowledged as one of the most severe across all manufacturing sectors, marked by unsustainable emissions, intensive resource usage, and toxic outputs (Niinimäki et al., 2020). The rapid expansion of fast fashion has aggravated these issues by encouraging overproduction and systemic inefficiencies that strain planetary boundaries. The absence of robust monitoring tools across fragmented global supply networks has further complicated accountability for environmental harm.

The fashion industry is responsible for an estimated 4–10% of global carbon emissions, outpacing the aviation and maritime sectors combined (UNEP, 2025). The fast fashion model is a major driver, incentivizing overproduction through short turnaround cycles and consumer demand for low-cost garments. For instance, some brands release 52 micro-seasons yearly, churning out products at unsustainable rates (EPRS, 2024). The logistical operations required to support this model—including global transportation, warehousing, and reverse logistics—compound the sector's carbon intensity. Moreover, overproduction leads to vast quantities of unsold inventory; the Ellen MacArthur Foundation (2022) estimates that approximately 30% of manufactured clothing is never sold, ultimately incinerated or dumped in landfills. This overproduction not only inflates emissions but creates a cyclical waste loop. The GFA (2023) warns that fashion's emissions could surge by 50% by 2030 without corrective measures.

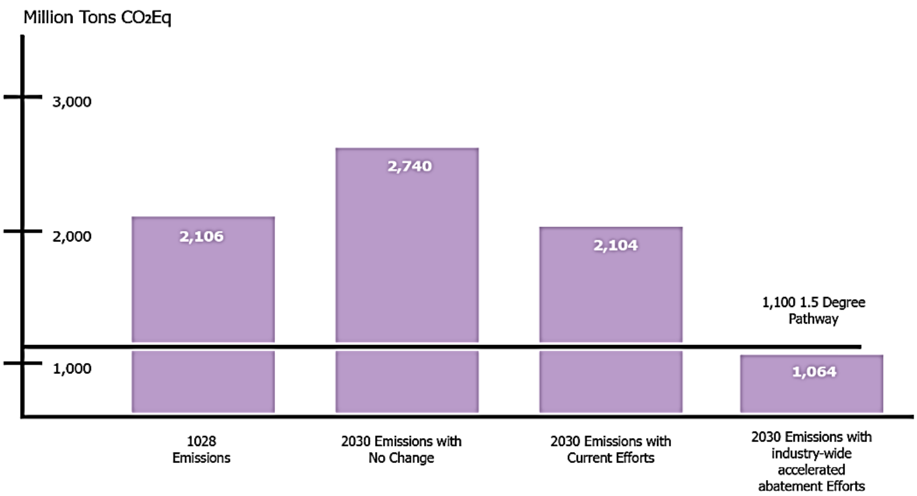

Figure 16: Current and Estimate Carbon Emissions in the Fashion Sector
Source: (Wren, 2022)

Current Environmental, Social, and Governance (ESG) disclosures are often voluntary and unaudited, enabling brands to greenwash practices while continuing carbon-intensive operations. Alotaibi et al. (2024) explain that Blockchain systems, through immutable ledgers, offer a corrective by enabling real-time emissions data logging across manufacturing nodes, thereby tightening scope three emissions accountability.

The textile sector is the second-largest consumer of the world's freshwater resources. Cotton production alone requires 2,700 liters of water to produce a single shirt, equivalent to one person's drinking needs for 2.5 years (Garcia, 2024). In regions such as Central Asia and India, where irrigation systems are already under stress, fashion's water demand poses a significant environmental and social risk. Moreover, dyeing and finishing processes are responsible for 20% of global industrial water pollution, with 200,000 tons of dyes lost annually in effluents (EPRS, 2024). Despite initiatives like the Zero Discharge of Hazardous Chemicals (ZDHC), enforcement remains weak, particularly in supplier-dominated contexts like Bangladesh and Vietnam (ZDHC, 2023). Without traceable water usage logs, many suppliers underreport discharge levels or illegally dispose of untreated wastewater into local ecosystems (UNEP, 2025). Blockchain-based smart contracts could mitigate this by automating compliance audits, recording volumes of water used, chemicals employed, and filtration standards met, thus holding suppliers to verifiable environmental performance metrics.

Textile production heavily relies on hazardous chemicals such as azo dyes, phthalates, and formaldehyde substances linked to cancer, hormonal disruption, and ecosystem degradation. The European REACH Regulation (2016) mandates chemical tracking, but in globalized supply chains, enforcement is inconsistent. Most brands, such as Zara and Nike, lack visibility into tier-2 and tier-3 suppliers where raw material processing and dyeing occur Chu, 2016; McKinsey & Co., 2024). This opacity allows for continued non-compliance with global safety norms. Blockchain can bridge these gaps by creating decentralized, time-stamped chemical inventories. For example, Beers et al. (2022) state that each dye or solvent used at any processing stage could be assigned a unique transaction ID, visible to regulators, brands, and third-party certifiers. This transparency would empower ethical sourcing teams to reject materials sourced through non-compliant channels and encourage upstream accountability. Moreover, by integrating with Digital Product Passports (DPPs), blockchain documents chemical inputs from origin to disposal, meeting growing demands for chemical transparency under the EU Green Deal (EPRS, 2024). Overall, the environmental challenges in fashion are systemic, concealed beneath a fragmented, multi-tiered supply architecture. Traditional methods of monitoring ecological harm, such as third-party audits and voluntary disclosures, have failed to enforce compliance or halt degradation (Thoti et al., 2024). Blockchain provides a paradigm shift, not by merely digitizing supply chains but by fundamentally altering their accountability structures.

2.6.2 Social Injustices and Labor Exploitation

The global fashion industry's supply chains are marred by deeply entrenched social injustices, ranging from wage theft to forced labor. These issues are exacerbated by production networks decentralized and opaque nature, especially in countries with weak labor protections and governance frameworks. Blockchain technology, though not a panacea, presents viable mechanisms for introducing accountability and traceability, particularly verifying employment practices and wages across tiers (Venkatesh et al., 2020). Wage theft and informal labor remain pervasive due to extensive subcontracting practices. Major brands often outsource production through multi-tier supplier structures, enabling cost minimization and distancing themselves from the realities of labor abuse. Subcontracted workers—many lacking formal contracts—are frequently paid below the minimum wage, if at all. According to the Clean Clothes Campaign (2022), suppliers across Pakistan defaulted on wage payments during 2022, impacting over 400,000 workers. Documentation is routinely falsified to present compliance during brand audits, and with each additional tier, accountability further diminishes. This informalization of labor is systemically embedded, allowing brands to profit while disclaiming responsibility for violations committed by "indirect" partners (Alghababsheh and Gallear, 2022).

The consequences of such neglect are not merely economic but often life-threatening. The 2013 Rana Plaza collapse, which killed over 1,100 garment workers, laid bare the exploitative undercurrents of global fashion production. A decade later, recent audits revealed that fire exits remain blocked, buildings lack structural certification, and workers report being denied breaks in high-heat conditions (Labor Behind the Label, 2024). Blockchain can ensure real-time, tamper-proof reporting of safety audits and labor conditions, holding suppliers accountable and preventing negligence. Despite introducing factory inspection regimes, meaningful improvements have stalled due to a lack of enforceability and real-time transparency. Smart contracts, when deployed via blockchain systems, offer transformative possibilities: they can automate wage disbursement only after safety compliance is verified, thus tying financial flows to ethical outcomes (Saberi et al., 2019). One of the gravest contemporary concerns is forced labor, often concealed within upstream segments of global value chains. The Xinjiang cotton controversy illustrates how state-sanctioned forced labor can infiltrate supply chains under the guise of legal sourcing. Brands have struggled to dissociate themselves from these abuses due to intent and a lack of granular traceability systems. Despite public pledges to eliminate unethical sourcing, a 2022 Australian Strategic Policy Institute report identified at least 82 global fashion brands linked to Uyghur forced labor (James, 2022). Traditional traceability methods, paper trails, and voluntary disclosures fail to capture this level of detail. Blockchain's decentralized, tamper-resistant ledger offers a possible corrective, enabling the creation of immutable records of cotton origin, wage receipts, and employment authorizations at each supply node (Chaudhuri et al., 2023).

Furthermore, opacity in employment contracts and recruitment practices fuels modern slavery. Workers recruited through informal networks often incur debt bondage or work without any grievance mechanisms. These conditions remain hidden until exposés or disasters make them public. Integrating blockchain into hiring workflows can embed transparency from recruitment through payment (Sareddy, 2022). For instance, Christ and Helliar (2021) workers' digital contracts could be stored on-chain, visible to regulators and NGOs, while being immutable to manipulation by employers. However, such implementations must be ethically designed to protect worker identities and adhere to privacy frameworks like GDPR, avoiding surveillance misuse under transparency (Renuka et al., 2025). Blockchain's promise hinges on stakeholder buy-in and ethical configuration. Without consensus on data standards, human rights protections, and legal interoperability, blockchain risks becoming another performative tool for brands to claim responsibility while evading it (Beshkardana, 2023). Yet, Cheesman (2022) with deliberate institutional design, blockchain can challenge the systemic impunity embedded in global fashion labor structures.

2.6.3 Regulatory Pressures and Legal Non-Compliance

The global regulatory landscape surrounding corporate sustainability is undergoing a fundamental transformation, placing fashion supply chains under unprecedented scrutiny. The introduction of legally binding frameworks such as the European Union's Corporate Sustainability Due Diligence Directive (CSDDD) has set a new benchmark for supply chain accountability. CSDDD requires large companies operating in or selling to the EU to identify, mitigate, and report on human rights abuses and environmental risks throughout their value chains (European Commission, 2024). This expands compliance requirements beyond tier-1 suppliers and into the murky domains of tier-2 and tier-3 operations, where most labor and ecological violations occur. Meanwhile, Forge ESG (2025), the UK Modern Slavery Act 2015 mandates companies to report annually on their actions to eradicate slavery and trafficking from their supply chains. However, Crane et al. (2019) suggest widespread underreporting, vague disclosures, and weak enforcement mechanisms have rendered compliance more symbolic than substantive. Traditional auditing mechanisms have largely failed to meet the demands of these new regulations. Supplier self-assessments and third-party audits, once the dominant compliance tools, are increasingly exposed as compromised (McGrath et al., 2021). Reports of staged audits, bribery, and falsified documentation plague high-risk manufacturing hubs. For example, in Bangladesh, several audits conducted by internationally certified firms have later been found to overlook serious workplace violations, including child labor and hazardous conditions (Bureau of International Labor Affairs, 2023) (see Fig 11). Such incidents undermine the credibility of due diligence and expose brands to legal liability and reputational damage. Regulatory bodies are now beginning to penalize misleading disclosures and greenwashing more aggressively. Notably, the French government recently fined a fast fashion retailer for advertising misleading environmental claims, setting a precedent for greater enforcement of sustainability marketing (Sammons, 2024).

Blockchain technology emerges as a response mechanism to these gaps by offering immutable, tamper-proof ledgers that document each production stage in real time. Blockchain enables traceable and auditable supply chain records that reduce reliance on episodic audits. Smart contracts can automate compliance checks, such as confirming wage payments or monitoring emissions thresholds, creating a continuous assurance mechanism (Sanni, 2024).

Children	Age	Percent of Population
Working	5 to 14	9.2% (Unavailable)
Hazardous Work by Children	7 to 17	Unavailable
Attending School	5 to 14	88.4%
Combining Work and School	7 to 14	8.2%

Figure 17: Statistics on Children's Work and Education
Source: Bureau of International Labor Affairs (2023).

A significant hurdle, however, lies in compliance complexity across jurisdictions. Multinational fashion brands operate in diverse legal regimes with conflicting regulatory expectations. The inconsistency between data protection laws in the EU (e.g., GDPR) and data residency requirements in countries like India or Vietnam creates a patchwork of legal obligations (Kshetri, 2022). Without harmonized digital systems, brands face duplication of effort and compliance fatigue. Emerging tools such as the EU's Digital Product Passport (DPP), expected by 2027, aim to streamline ESG data collection and standardize disclosure requirements across borders (EPRS, 2024).

2.6.4 Rise of Consumer Activism and Reputational Risk

During the last few years, consumer activism has become a determining factor in corporate responsibility in the fashion industry. The behavior of young consumers, among whom the role of millennials and representatives of Gen Z prevails as the leading buying group, is highly value-conscious. According to McKinsey & Company (2022), over three-quarters of Gen Z customers perceive sustainability as an essential element in the brand choice. Social platforms have pushed this trend further and put campaigns like PayUp (2020) or the yearly campaigns by Fashion Revolution in the limelight to create a mass protest against the most prominent fashion brands suspected of engaging in unethical practices (Clean Clothes Campaign, 2020). According to the BBC (2024), some retail companies, such as Shein, have faced boycotts and reputational damage because of their inexplicable supply chain sources and accusations of labor exploitation. The mutual loss of consumer confidence can be mostly blamed on unreliable sustainability statements and greenwashing. UNEP (2023) reports that 60 per cent of the so-called green status of fashion brands is deceptive or unsupported. As a result, brands are forced to face more scrutiny by platforms like Good On You or activist groups and organizations, which play a key role in the assessment process of brand equity and investor confidence. The solution may be found in blockchain technology with thick, decentralized ledgers whose history cannot be tampered with to record the growth of a product, beginning with fiber to the finish. Using QR codes, the prevailing provenance, carbon footprint, and wage-compliance could be checked, thus adding another layer to the trust reinforced with the transparency (Gariba et al., 2024). With reputational loss in the food business being a direct consequence of monetary loss, verifiable transparency is no longer a luxury and is quite clearly a mandatory market condition.

2.7 Blockchain Alignment with SDGs and ESG Goals

2.7.1 Blockchain's Contribution to SDG 12: Responsible Consumption and Production

Sustainable Development Goal (SDG) 12—Responsible Consumption and Production, calls for systemic changes in how goods are manufactured and consumed. Specifically, sub-targets such as 12.2 (sustainable management of natural resources), 12.6 (adoption of sustainable practices and reporting), 12.7 (sustainable public procurement), and 12.8 (awareness for sustainable lifestyles) demand increased accountability, transparency, and efficiency from industries like fashion that have historically operated with opaque and extractive practices (UN SDGs, 2023). With its decentralized, tamper-proof nature, blockchain technology offers a powerful tool to support traceability and data integrity throughout the fashion supply chain. As fashion brands face increasing scrutiny for unsustainable practices, blockchain enables real-time recording of material provenance, energy and water consumption, and emissions at each stage of the production cycle (Gariba et al., 2024). Through cryptographically secured ledgers, stakeholders can access immutable records that document sourcing methods, supplier certifications, production conditions, and end-of-life treatment of garments. For instance, the Aura Blockchain Consortium, initiated by luxury brands such as LVMH, Cartier, and Prada, enables customers to trace a product's origin, raw materials, and environmental impact from factory to shelf. The initiative supports SDG 12 by promoting responsible sourcing, minimizing information asymmetry, and increasing consumer awareness (Aura Blockchain Consortium, 2024). These features reflect operational innovation and a growing commitment to ethical transparency in brand strategy.

Furthermore, blockchain aligns with circular economy principles, a key objective under SDG 12. Blockchain's ability to map a product's lifecycle from manufacture to resale or recycling contributes to a closed-loop system. For example, product passports that contain details about repair history, material composition, and recycling options can be stored on blockchain networks, encouraging reuse and reducing landfill waste (EPRS, 2024). As such, blockchain serves as both a digital infrastructure and an enabler of behavioral and process change toward sustainability. However, the impact of blockchain in advancing SDG 12 remains limited by slow adoption rates and systemic barriers. Despite pilot initiatives, widespread implementation across fast fashion and mid-tier brands is lacking. According to Singh et al. (2022), most brands still use conventional data systems that are neither interoperable nor real-time, hindering material traceability and supply chain accountability. This slow adoption is partially due to technological illiteracy, high costs, and poor supply chain integration in many regions, especially among SMEs in the Global South (Bag et al., 2023). From a theoretical lens, Institutional Theory offers a compelling explanation for this lag. Although coercive and normative pressures such as the EU Corporate Sustainability Due Diligence Directive (CSDDD) and growing consumer activism push firms towards blockchain-based transparency systems, the absence of clear regulatory mandates for blockchain implementation dampens its prioritization (DiMaggio and Powell, 1983). Thus, while institutional forces encourage alignment with SDG 12, they have yet to create a robust, compulsory framework that drives uniform adoption.

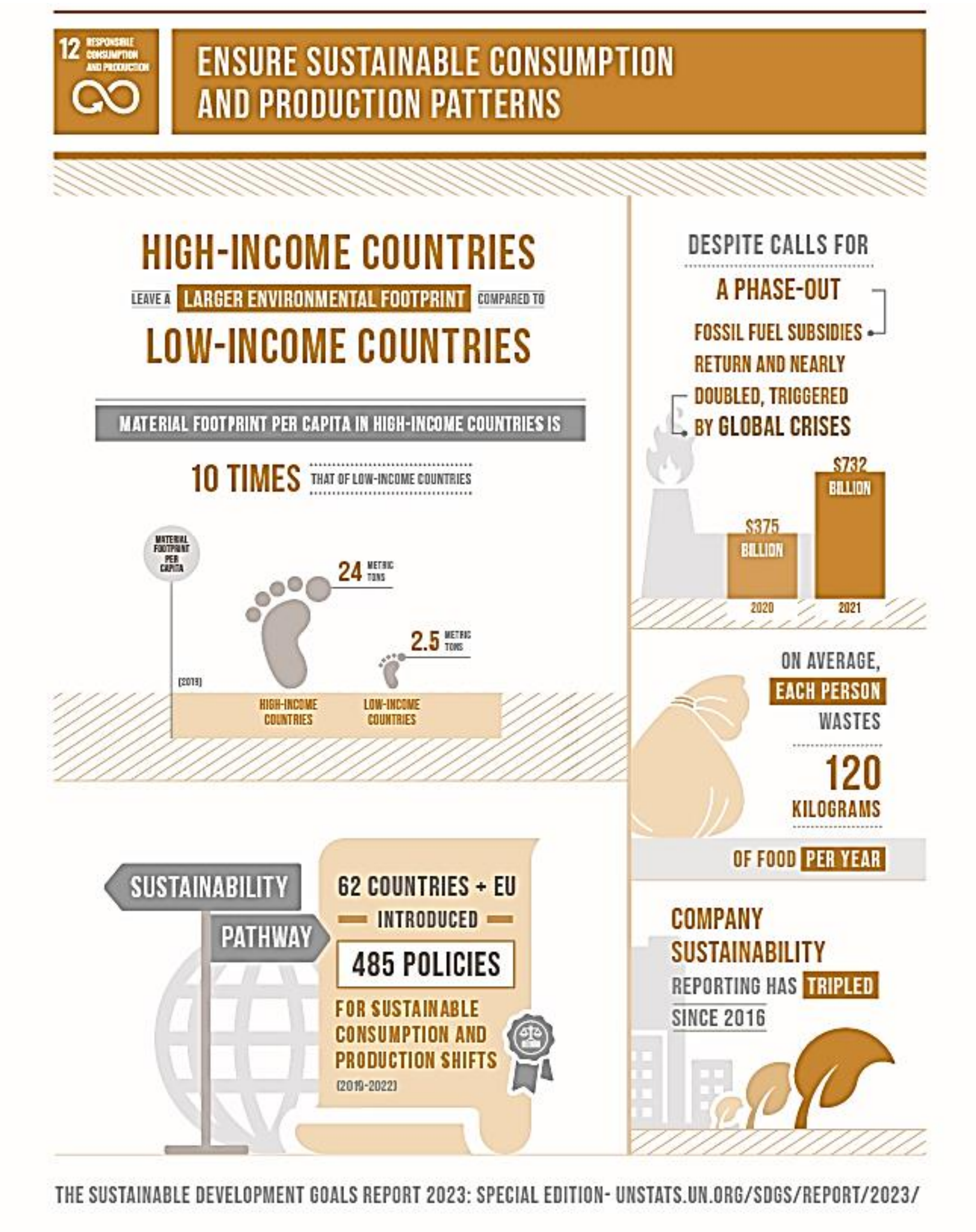

Figure 18: SDG 12
Source: United Nations (2023)

Moreover, Calvão and Archer (2021) argue that blockchain’s promise of data-driven sustainability can paradoxically create a digital divide, with well-capitalized firms leading the way while smaller suppliers are left behind. This undermines the inclusive ethos of SDG 12. Without financial and technical assistance to low-tier suppliers, blockchain may become a performative transparency tool rather than a genuine catalyst for systemic transformation.

2.7.2 Blockchain and its Alignment with SDG 8 and SDG 9

In addition to supporting SDG 12, blockchain technology shows potential alignment with SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation, and Infrastructure). SDG 8 promotes sustained, inclusive economic growth and productive employment, while SDG 9 focuses on building resilient infrastructure and fostering innovation. Both are highly relevant to fashion supply chains, which are plagued by labor exploitation, wage theft, and underinvestment in digital infrastructure — especially in the Global South (ILO, 2023).

Blockchain enhances alignment with SDG 8 by enabling verifiable and transparent employment records, wage disbursement logs, and worker identity tracking. These functions help mitigate labor right violations and reduce reliance on opaque subcontracting networks. For instance, blockchain-based wage tracking systems like TrusTrace and Provenance have been used in pilot projects to ensure that factory workers receive legally compliant wages and benefits (Saxena et al., 2022). Worker cooperatives and unions can also access these immutable records, supporting social auditing and grievance redressal. However, this assumes digital access and data literacy among workers — conditions not guaranteed in low-income production zones. Critics argue that blockchain's promise of labor empowerment may reinforce the digital divide if not paired with capacity-building initiatives (Calvão and Archer, 2021). Without connectivity and governance safeguards, data-driven oversight risks becoming extractive rather than emancipatory.

SDG 9 emphasizes the need for sustainable industrialization and digital infrastructure— areas where blockchain can support supply chain innovation. Blockchain’s decentralized architecture enables the development of shared databases across supply chain tiers, improving coordination between manufacturers, suppliers, logistics providers, and retailers. This real-time information sharing enhances productivity, reduces bottlenecks, and strengthens resilience against global disruptions like pandemics or geopolitical shocks (Wang et al., 2020). Yet, there are concerns over blockchain's fragmented implementation. Most solutions remain proprietary, limiting interoperability and inclusive participation. Furthermore, the costs of blockchain infrastructure—including hardware, software development, and cybersecurity—remain prohibitive for SMEs, especially in South Asia and Sub-Saharan Africa (Bag et al., 2023).

While blockchain aligns theoretically with SDG 8 and 9, practical implementation is uneven and exclusionary. Without regulatory frameworks that mandate data inclusivity and provide financial support to small-scale actors, the technology risks amplifying existing inequalities. Therefore, for blockchain to be a genuine enabler of decent work and resilient infrastructure, its deployment must be supported by robust public-private partnerships, legal reforms, and inclusive design principles.

2.7.3 Blockchain and the Environmental (E) Dimension of ESG

Environmental sustainability is a cornerstone of ESG strategy, and blockchain technology is increasingly viewed as a tool that can enhance traceability, accountability, and environmental data reporting in fashion supply chains. The fashion industry contributes up to 10% of global carbon emissions, with significant ecological impacts from raw material sourcing, dyeing, manufacturing, and logistics (UNEP, 2025). Blockchain systems can support emission transparency by providing immutable, decentralized energy use records and carbon outputs across each production tier. Blockchain's environmental potential lies in its capacity to support automated carbon accounting. For example, blockchain-enabled platforms integrated with Internet of Things (IoT) sensors can measure and log emissions in real time at factory or logistics nodes. These sensors capture data on electricity consumption, fuel usage, and industrial heat, which is then stored on a blockchain that cannot be altered. This system helps brands calculate Scope 1, 2, and 3 emissions with higher accuracy and reliability (Treiblmaier, 2019). Sharma (2020) reports that platforms like VeChain have partnered with fashion brands like H&M and Babyghost to track product origin, CO_2 output, and water consumption throughout the product lifecycle. These pilots demonstrate that blockchain can build environmental data registries that support traceability and inform eco-design improvements.

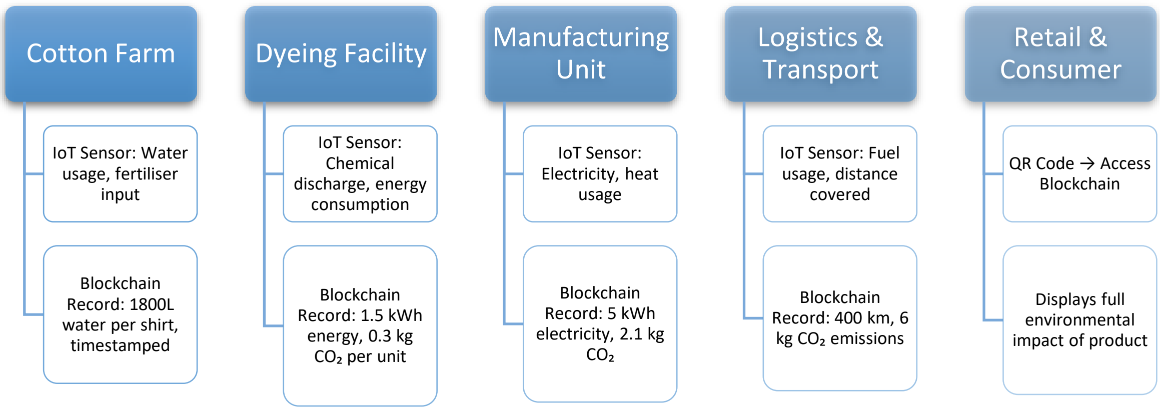

Figure 19: Blockchain-Enabled Environmental Data Tracking in Fashion Supply Chain
Source: Author's work

Moreover, blockchain aids waste management. Fashion brands often lack insight into pre- and post-consumer textile waste, contributing to over 92 million tons of landfill annually (UNEP, 2025). Blockchain can track textile inputs, offcuts, and defective batches at manufacturing units, logging what is discarded and what is reclaimed. At the post-consumer stage, used garments entering recycling or resale channels can be traced using blockchain-based Digital Product Passports (DPPs), ensuring materials are recycled or reused efficiently rather than disposed of improperly (EPRS, 2024). Resource intensity monitoring is another area where blockchain shows promise. Water usage during cotton cultivation and chemical dyeing processes remains largely unreported. Blockchain can verify the volume of water and chemical agents used at each stage. For example, Agrawal et al. (2021) demonstrate that textile processing plants can record their inputs and outputs on a blockchain, which becomes available for audit and certification bodies to verify against sustainability claims. This adds credibility to brand claims regarding low water footprint or safe chemical use (Jenkins, 2023).

Despite these benefits, blockchain's energy consumption paradox raises concerns. Public blockchains such as Bitcoin and Ethereum originally used proof-of-work (PoW) consensus mechanisms, which consume vast amounts of electricity. Omrane et al. (2024) claim that Ethereum's recent shift to proof-of-stake (PoS) in 2022 reduced its energy consumption by over 99%, demonstrating that greener blockchain solutions are emerging. However, most fashion applications favor permissioned blockchains (e.g., Hyperledger, VeChain), which are inherently more energy-efficient and scalable. Blockchain also plays a pivotal role in supporting regulatory compliance. The International Sustainability Standards Board (ISSB) climate disclosure standards mandate granular reporting on carbon emissions and climate risks (Mulligan et al., 2024). Blockchain's immutable and auditable nature makes it well-suited to meet these demands. By ensuring data accuracy and integrity, blockchain allows firms to submit verifiable ESG data to regulators and investors, reducing the risk of greenwashing (Saxena et al., 2022). Hajiyev (2024) also states that the EU Green Deal and Corporate Sustainability Reporting Directive (CSRD) require companies to maintain digital environmental performance records, something blockchain is structurally designed to support.

2.7.4 Blockchain and the Social (S) Dimension of ESG

The social dimension of Environmental, Social, and Governance (ESG) frameworks primarily concern labor rights, working conditions, equitable pay, and fair treatment of workers. The fashion industry, with its extensive outsourcing and subcontracting networks, especially in developing economies, faces persistent challenges in these areas (Narula, 2019). Blockchain technology presents promising interventions, although its success depends on the context-sensitive design, inclusion, and enforcement mechanisms.

One of the most discussed applications is wage verification. Blockchain enables immutable records of employment contracts, attendance logs, and payment transactions. Smart contracts, programmable code that self-executes when predefined conditions are met, can ensure that wages are automatically disbursed when hours worked or task completion is verified (Dutta, 2020). This could prevent wage theft, which remains rampant in fashion supply chains. For instance, during the COVID-19 pandemic, workers in Bangladesh under brands like H&M, Zara, and GAP reported billions in unpaid wages or retrenchments without severance (Al Jazeera, 2023). A blockchain-based system would log work data transparently and make it accessible to unions, workers, and third-party auditors, thereby reducing opportunities for contractual manipulation. Similarly, the potential of blockchain in forced labor detection lies in its ability to validate employment pathways. Blockchain systems can embed biometric verification and timestamped entries, thereby tracing the voluntariness of employment contracts across borders (Sharma and Dwivedi, 2024). For instance, BBC (2021) reports that Xinjiang, known for its cotton exports, has faced backlash from global brands such as Nike and H&M over forced labor allegations. Brands sourcing cotton from the region often lacks traceability below tier 2 or 3 suppliers. Blockchain-enabled supply chain solutions, like those trailed by companies such as Everledger, can provide "proof of origin" for raw materials by tracking each handoff point along the supply chain (Everledger, 2021).

Another social application includes creating immutable grievance redressal logs and empowering civil society actors. NGOs and unions often find it challenging to monitor factory-level practices due to a lack of access to data. Blockchain offers a transparent ledger where worker complaints, third-party audit findings, and remediation efforts can be recorded without the risk of post hoc data manipulation (Gupta et al., 2024). Such access democratizes oversight, encouraging bottom-up accountability. While initiatives like the Better Work Programmed have attempted to foster such platforms, Ahmed (2025) explains that blockchain enhances their integrity through decentralization and immutability. However, these benefits are accompanied by significant limitations. First, UNCDF (2023) states that many garment workers in Bangladesh might not have access to the devices or digital literacy required to interact with blockchain tools. This creates an inclusion paradox where a solution meant to protect workers may reinforce digital exclusion. Second, the fear of surveillance persists. Awumey et al. (2024) assert that if not properly anonymized, blockchain data, mainly biometric IDs or wage logs, could be used to monitor, penalize, or intimidate workers. Hence, strong governance protocols are required to ensure ethical data use.

From a regulatory standpoint, blockchain's social applications can support compliance with global norms. For instance, the UK Modern Slavery Act (2015) and the EU's CSDDD mandate supply chain transparency and the mitigation of forced labor. Similarly, the Global Reporting Initiative (GRI) standards for human rights and the OECD Due Diligence Guidance for Responsible Supply Chains emphasize auditable disclosures of social risks. Blockchain, through its immutable data records and audit trails, can facilitate these disclosures and reduce the cost of compliance audits.

2.7.5 Blockchain and the Governance (G) Dimension of ESG

Within the ESG framework, governance defines the structures, practices, and accountability mechanisms that enforce ethical decision-making, ensure transparent disclosures, and demand regulatory compliance (Saleh et al., 2020). Marques et al. (2025) explain that traditional governance mechanisms have repeatedly failed to provide real-time, verifiable information on sourcing, labor, and environmental impact in fashion supply chains. Through decentralized data architecture and tamper-proof ledgers, Oriekhoe et al. (2024) state that blockchain technology is emerging as a transformative tool that enhances supply chain governance by embedding transparency, auditability, and accountability into the core of operations. One of the key applications of blockchain in the governance domain is automated ESG compliance through real-time data audits. Blockchain enables stakeholders, regulators, consumers, and investors to access immutable data on supply chain activities, certifications, and sustainability metrics. Reporting obligations (e.g., sustainability KPIs or third-party certification renewals) can be automatically triggered, tracked, and verified through programmable smart contracts without human intervention (Sanni, 2024). This automation reduces compliance risks, enhances data consistency, and curbs the practice of backdated or falsified disclosures (Saxena et al., 2022).

Real-time validation of certifications such as Fair Trade, Global Organic Textile Standard (GOTS), and Zero Discharge of Hazardous Chemicals (ZDHC) is another governance innovation enabled by blockchain. Instead of relying on paper documents or PDFs that can be easily altered, digital certificates can be anchored to blockchain ledgers and linked with product IDs (Saleh et al., 2020). This linkage helps fashion brands and regulators verify the authenticity and continuity of ethical sourcing claims. The VeChainThor platform, for example, has enabled several fashion houses to map and display verified certifications on-chain, improving stakeholder confidence (Bitget, 2024). Importantly, blockchain acts as a barrier against greenwashing—a major governance failure in the sustainability arena. Greenwashing arises from unverifiable or misleading environmental claims (Nygaard and Silkoset, 2023). Through distributed ledgers, stakeholders gain access to immutable, time-stamped data that supports (or disproves) a brand's environmental or social claims. In this regard, platforms like Everledger (2021) have demonstrated how blockchain-based tracking can authenticate claims around conflict-free diamonds, which can be extended to fashion commodities such as cotton or leather. LVMH has implemented a similar protocol via the Aura Blockchain Consortium to verify sourcing, production history, and ownership, thus improving brand governance (Aura Blockchain Consortium, 2024). Blockchain creates several challenges, even though it is desirable for real-time certification. To begin with, it does not ensure whether the input data is accurate, thus facilitating false claims. This poses a particular problem to data-intensive applications and provenance systems in general. Second, it is costly to implement, and since no universal standard is realized, incorporating blockchain platforms in various sectors is complicated. Third, not all suppliers give a green light to transparency, and physical inspection is necessary. Fourth, the service level of the blockchain may be suboptimal, and the laws creating a backlash against the data-privacy regimes posing obstacles, such as GDPR, can be seen as legal tensions according to the properties of blockchains that are inalterable (Saleh et al. 2020; Nygaard and Silkoset 2023).

Institutional Theory provides a lens to understand why firms adopt such governance-enhancing technologies. Beyond efficiency, firms experience normative and coercive pressures from regulatory agencies, investors, and NGOs to improve transparency and legitimacy. Blockchain, in this context, is not only a technical tool but also a symbolic asset that demonstrates proactive compliance, ethical leadership, and brand legitimacy (DiMaggio and Powell, 1983; Treiblmaier, 2019). It positions firms to meet growing expectations around good governance while enhancing reputation in a competitive marketplace. Furthermore, blockchain aligns well with the EU's Corporate Sustainability Reporting Directive (CSRD), which mandates the collection of auditable, accurate, and comparable ESG data (Sayilir et al., 2025).

2.7.6 Integration with International Sustainability and Reporting Frameworks

Blockchain technology offers a promising solution to the longstanding fragmentation in global sustainability reporting frameworks. Key initiatives such as the International Sustainability Standards Board (ISSB), the Global Reporting Initiative (GRI), and the EU's Corporate Sustainability Reporting Directive (CSRD) demand accurate, real-time, and verifiable disclosures of ESG metrics across operations and supply chains. However, organizations like H&M continue relying on decentralized, spreadsheet-based, or manual systems prone to inconsistency, greenwashing, and audit failure (Salomone, 2023). With its tamper-proof, decentralized ledger, blockchain directly addresses these issues by enabling immutable, auditable, and synchronized data entry across multiple actors in a supply chain. The Digital Product Passport (DPP) initiative under the European Green Deal offers a pertinent example. Mandated to be in place by 2027, the DPP requires brands to disclose a product's complete lifecycle data, including material composition, repairability, and recyclability. According to the European Parliamentary Research Service (EPRS, 2024), blockchain technologies are central to achieving the DPP's goal of traceable and interoperable data, allowing decentralized access and secure storage across producers, regulators, and consumers. Despite these benefits, blockchain's integration into international reporting remains nascent. A lack of standardization in blockchain platforms, incompatible data structures, and limited regulatory guidance on blockchain use within GRI or

ISSB protocols hinder its broader adoption. For blockchain to fulfil its harmonizing potential, global policy consensus on data formats, interoperability protocols, and auditing frameworks is essential (Rıos, 2024). Blockchain risks becoming another siloed tool rather than a unifying infrastructure for sustainability reporting.

2.8 Comparative Analysis of EU Digital Product Passport (DPP) and Blockchain-Based Transparency Models in Fashion Supply Chains

2.8.1 Regulatory Origins and Policy Intentions

The Digital Product Passport (DPP) of the European Union falls within the larger regulatory framework, trying to integrate the concept of circularity and transparency in the supply chain within the European Green Deal and the Circular Economy Action Plan (CEAP). Established in 2020, CEAP prioritizes this through product design and improved consumer rights, as over 80 % of environmental impacts of a product are formed during its design (European Commission, 2020). To make that ambition operational, in 2022, the Eco-design for Sustainable Products Regulation (ESPR) was proposed, which will require the creation of Digital Product Passports in priority sectors such as textiles, batteries, and electronics, making product sustainability data more available at all stages of the product lifecycle (EPRS, 2024). The DPP aims to impose product-level traceability, durability, repairability, and recyclability. Incorporating standardized data on environmental impact into individual product digital identities, where consumers, recyclers, and regulators can access them (through QR codes or with RFID), should be used to raise consumers, recyclers, and regulators to make informed decisions and strictly enforce compliance and facilitate responsible production and consumption (Worldly, 2023). Therefore, the DPP is a top-down policy tool with clear mandates, implementation schedules, and compliance requirements.

On the contrary, the concept of transparency with blockchain has developed bottom-up, where the underlying technology is innovative. Promoted by companies like LVMH, Patagonia, and Everledger, these models react to trends in the market and investment in ESG, as well as consumers' desire for traceability. They are decentralized technology strategies that are reaching similar goals, traceability, transparency, and circularity without implementation by law. In contrast with DPPs, these systems are not obligatory and tend to change more rapidly than policy frameworks. The comparison throws light on a fundamental divide: on the one hand, DPPs monetize transparency by enshrining it in legislation, on the other, blockchain models operate based on technological trust, participation-led adoption, and reputable interests. The convergence vs. divergence of these two models will have rather significant implications that will affect supply chain governance in the future.

2.8.2 Functional Architecture and Technical Infrastructure

The European strategy of the platform economy (ESPR) infrastructure is centralized, and it is in the form of the Digital Product Passport (DPP) framework of the European Union. Individual DPPs contain a unique product identifier code that is usually deployed as a QR code or Near-Field Communication (NFC) tags but is connected to a central registry maintained within the EU (Worldly, 2023). This database contains layered lifecycle data, including product composition, origin and source of materials, repair information, durability, and recyclability information. It is supposed to be connected with the EU digital identity services, and standardized taxonomies and data schemes constrain it to guarantee the cross-single market interoperability (EPRS, 2024). In comparison, systems that use blockchain work through decentralized distributed ledgers. The use of such platforms as Ethereum, Hyperledger Fabric, and VeChain allows data entries to be not only cryptographically secured, time-stamped, and made immutable between more than two nodes (Casino et al., 2019). The logic automated in smart contracts includes supplier authentication and emissions monitoring, and stakeholders can have permissioned access to blockchains based on the consensual provision. For example, the Aura Blockchain Consortium by LVMH allows product tracing on a private chain, and Everledger provides immutable provenance data about luxury goods and diamonds (Everledger, 2024).

The primary difference between these architectures is the issue of data governance. DPPs are centrally administrated and government-regulated, which provides regulation but may store all the information in a restricted location, leaving it susceptible to attack. Despite their resilience and clarity, blockchain systems face such barriers as interoperability among chains, excessive energy consumption in Proof-of-Work systems, and a low level of scalability during high transactional demands, as well as high costs of integrating with legacy enterprise systems by small and medium-sized enterprises (Kouhizadeh et al., 2021). DPPs guarantee compliance and standardization but rely on institutional trust; blockchain platforms substitute institutional trust with algorithmic consensus, decentralizing control at the cost of technical maturity. Each of the two architectures provides traceability, but they have different trade-offs in realizing transparency, power, and resilience that interest policymakers and the industry.

2.8.3 Data Accuracy, Immutability, and Greenwashing Prevention

The major drawback of the Digital Product Passport (DPP) used in the European Union lies in its dependence on the data provided by manufacturers and third parties, that is, verification. The European Commission has established standardized data-entry procedures and introduced data accuracy by subjecting it to periodic audits. However, the DPP lacks technical instrumentation to record data proofreads and writes (EPRS, 2024). This puts the system at the risk of green washing, especially in the case of a fragmented textile supply chain characterized by subcontracting and oblique levels that undermine traceability. In contrast, blockchain-enabled transparency-based approaches have real-time, decentralized logging of supply chain information using cryptographic techniques: data entries are all time-stamped and shared among multiple nodes, and the record is irrevocable once established (Casino et al., 2019). Oracle blockchain and smart contracts would allow fully automated verification, such as connecting emissions sensors with the carbon-accounting system, decreasing the reliance on human verification and audit delays (Saberi et al., 2019). In this regard, blockchain makes possible end-to-end accountability, which will provide more deterrence to misreporting and manipulation.

Comparisons with other cases also highlight these differences. Using blockchain-based disclosures, including the carbon-management platform developed by VeChain, fashion brands can track CO_2 or water consumption on a granular, tiered basis across production phases (VeChain, 2023). These data are being updated and are dynamic and verifiable on the chain. In contrast, DPP entries are more fixed and updated at intervals (as a snapshot) than continuous performance measures. This type of structure makes window-dressing of reputation possible, where the manipulation of favorable metrics with selective disclosure is allowed without the general lifecycle analysis. Accordingly, although the DPP represents a significant step forward in regulation, its usage of centralized, editable databases and self-reported data threatens shallow carbon-offsetting claims. Blockchain is not impeccable, but it provides stronger protection against greenwashing by providing cryptographic integrity, a traceable audit trail, and automation in verification.

2.8.4 Cost, Accessibility, and SME Readiness

Using the European Union Digital Product Passport (DPP) creates significant problems for small- and medium-sized enterprises (SMEs) within the fashion industry. The Eco-design for

Sustainable Products Regulation (ESPR) stipulates that companies must switch to a standardized digital format, incorporate lifecycle-tracking capabilities within products, and attach QR or NFC labels to the individual products. Seeing these digital needs requires high investment in IT infrastructure, staff training, and compliance management systems. Even though the EU gives technical support in the transition to SMEs, most companies do not have sufficient funds and operational capabilities to use DPP structures without third-party support (European Parliament Research Service [EPRS], 2024). Moreover, the continuous expenses required to maintain the system, not to mention the possibility of being audited by a third party, could create an unreasonable burden on smaller brands, increasing the NFRS compliance gap between large companies and SMEs.

Transparency systems through blockchain provide an unclear cost-accessibility status. Enterprises' ready applications like IBM Food Trust and Aura Blockchain require significant set-up fees and a high Degree of technical know-how, which restricts their use to large multinationals such as LVMH and De Beers. Comparatively, more streamlined platforms such as VeChain ToolChain and Provenance can have lower entry barriers and streamlined interfaces that can easily accommodate the involvement of SMEs with no or little blockchain fluency (VeChain, 2023). One of the solutions is usually based on a subscription model, where capital expenditure is lowered at the cost of data standardization. Blockchain systems operate as a decentralized cost-sharing system in a long-term value approach. For example, brands can use smart contracts to automate compliance or distribute tracking costs to suppliers. In contrast, there is centralization of responsibility of compliance under the DPP model, where retailers and regulators primarily engage in data consumption, as well as auditors of producers. DPP may leave SMEs struggling in vain, as they will not receive returns without a regulatory or shared-responsibility subsidy. Thus, despite comparable investment costs in DPP and blockchain solutions, the bottom-up agnostic and modular deployment and the decentralized cost-sharing infrastructure will offer greater inclination routes toward SME integration, especially in non-industrialized economies where not everyone is ready to be digital.

2.8.5 Stakeholder Engagement and Incentive Alignment

The Digital Product Passport (DPP), as mentioned in the Eco-design for Sustainable Products Regulation (ESPR) of the EU, focuses on institutional actors, such as regulators, recyclers, and customs authorities, whose goal is to improve the traceability and transparency of environmental data of products (EPRS, 2024). Its technocratic architecture is conducive to informed regulatory monitoring. Still, it has minimal interactive functionalities to enable a dynamic engagement with stakeholders, especially vulnerable parties like the factory workers or the non-governmental organizations. Conversely, there is the blockchain model of transparency, like LVMH Aura or Everledger, which is both decentralized and democratized in its form. The performance of these systems makes it possible to obtain a tamper-proof record of events throughout the supply chain, making the data available to a broader range of stakeholders. It could be with the option of permissioned NGOs, trade unions, and worker advocacy groups that can perform checks on employment conditions, wages, and audit information, which is another primary weapon against wage theft or bonded labor (Tapscott and Tapscott, 2020). Likewise, sustainability rating agencies and investors benefit from having the opportunity to access verifiable ESG in real time. In addition to balancing incentives, blockchain is also characterized by establishing trust by acting accordingly, not just complying. A case in point, the Cotton Blockchain Project in Bangladesh is harnessing the functionality of blockchain to verify wage payment and fair labor processes to generate both reputational and financial incentives to encourage ethical sourcing (ILO, 2023). In contrast, DPP risks becoming a compliance tick-box without developing a higher trust and responsiveness of stakeholders.

2.8.6 Circularity, Lifecycle Thinking, and Post-Consumer Tracking

Data Packaging Project (DPP) attempts to reinforce the circular economy and develop a common product-level environmental data, including recyclability, repairability data, etc. However, the present design is skewed towards cradle-to-gate and can barely provide room to track post-consumer milestones like reusing, resale, or regenerating the materials (European Parliamentary Research Service, 2024). The paradigm of circularity is significantly expanded with the White Paper-reflected models enabled by Blockchain. Circular ID and resale platforms enabled by VeChain can provide cradle to cradle traceability: records of numerous life cycles of different objects can be recorded: consumer resale, garment repair, and other recycling channels (CircularID, 2022). This real-time monitoring supports behavioral incentives (e.g., resale rewards) and brand responsibility towards their environmental legacy over the long term, primarily through automated sustainability, e.g., automatic carbon credits assigned to returned garments or updated provenance data whenever a garment is resold. In comparison, the DPP gathers product information at a tied point and makes minimal follow-up operations on the product. This factor limits its influence on perpetuated circular behaviors throughout life. Even though the DPP has a static structure that allows it to comply with the current regulatory frameworks, it fails to consider the adaptive aspects that would drive long-term circular practices. Blockchain systems are technically more demanding and complex but have a flexible architecture that can change with the changing sustainability goals and consumer trends. Therefore, blockchain may be favored over DPP to support the end-to-end traceability, nudges to behavior, and the infrastructure needed to support regenerative design in a fashion industry facing increasing pressure to engage in lifecycle stewardship.

2.8.7 Policy Harmonization and Global Scalability

The Digital Product Passport (DPP) is a core tool of the European Union Eco-design for Sustainable Products Regulation (ESPR). Still, it is more of an EU compliance-focused tool than a cross-border functional solution. This type of arrangement creates significant obstacles to Global South suppliers, who cannot qualify because of an insufficient digital or regulatory framework to provide in-EU specific data, and they become vulnerable to being locked out of the market. In contrast, blockchain-based transparency protocols, especially those on decentralized ledgers like Ethereum or VeChain, have built-in scalability independent of boundaries and can be easily implemented across heterogeneous regulatory jurisdictions. However, blockchain-based systems face interoperability challenges such as platform fragmentation, lack of technical harmonization, and compatibility issues with legal regulations like the General Data Protection Regulation (GDPR). As one example, data stored in public blockchains, which are immutable, can conflict with the GDPR right to be forgotten, which can be a challenge to data storage in a legally compliant manner. In addition, if the EU demands that the DPP be the only way to comply with imported products, the system might disadvantage small and medium-sized producers within the Global South and thus worsen the current imbalance in international trade. As a result, there has been increased demand for a hybrid governance paradigm combining the DPP's organized compliance model with the verifiability functions of blockchain. In these arrangements, blockchain may serve as an ethical layer that confirms DPP postulations and allows confidence in international supply chains without enforcing stringent technological requirements. Regulatory compliance based on decentralized verification is, thus, a much-needed harmony with an interoperability system that can lead to greater transformation of global supply chains in an equitable and inclusive system.

2.8.8 Tactical Evaluation of DPP versus Blockchain Models: Practical Superiority, Systemic Trade-offs, and Global Implications

Closely evaluating the DPP (Digital Product Passport) and the blockchain-based transparency schemes reveal significant discrepancies in implementation strategies, system adaptability, stakeholder interaction dynamics, and functional effectiveness. Despite both having the purpose of enhancing traceability and sustainability in supply chains, both frameworks differ significantly in technological implementation and institutional rationalization. Blockchain systems are more flexible in terms of an adaptability framework. The strict framework of the DPP and the centralized implementation imply that the process is not adaptable iteratively. Changes in the DPP framework through the regulatory system entail significant procedural politics and slow legislative processes in EU institutions (EPRS, 2024). On the other hand, blockchain platforms, notably those based on modular platforms like Ethereum or Hyperledger, allow constant technical refinement and adaptive innovation (Casino et al., 2019). This dynamic ability is paramount in the uncertain and changing environment of fashion supply chains, where consumer demands, sustainability criteria, and sourcing relationships are changing quickly. The programmability of Blockchain would further make compliance requirements changeable in real-time using smart contracts. Still, the DPP does not have this ability, and its standards-based compliance checklist is static.

In operational environments, blockchain platforms increase the auditability and verifiability of production networks. After being filed on a distributed ledger, the data becomes immutable and tamper-evident, turning it into high-integrity data accessible for review by all or groups of participants. This arrangement is a deterrent to backward manipulation-a problem particularly severe in industries prone to subcontracting, obfuscation, and greenwashing, like garments across South and Southeast Asia (Saberi et al., 2019). In comparison, decentralized production platforms (DPPs) are based on centralized databases where manufacturers report data. Although data audits every period are required, they can be quite resource-demanding and can be influenced by lobbying activities or simple compliance (EPRS, 2024). The trust mechanism algorithm integrated in blockchains forms a continuous audit trail that minimizes the role of third-party auditors and makes it more resilient to wrongful disclosure. Accordingly, the distributed verification of blockchain is not only an operational tool but also a systematic preventative measure against reputation laundering. The strategic orientation of these two systems is also evident in their motivational logic. DPPs are compliance-oriented mechanisms that aim to meet regulatory requirements by adhering to rigid data formats and schedules, instilling minimum standards with few incentives to raise the bar or be innovative in sustainability activities. On the other hand, Blockchain networks often include performance-pay mechanisms in tokenized incentives to circular actions, verifiable ESG reporting, or third-party audits, which can encourage responsible practices across various supply chain levels, including raw-material suppliers and end customers. The gamification of sustainability presented in blockchain interfaces, such as minting carbon tokens on low-impact materials, will, in all likelihood, help instill more participatory and change-making habits than the passive reporting system entrenched by the DPP.

The cost and equity implications of blockchain can be considered another, more serious sphere where its scalability benefits come to the fore. Blockchain-based systems and distributed procurement platforms (DPP) will require onboarding costs, with DPP based on integration with EU-certified databases and blockchain based on implementing the cryptography infrastructure. Unlike DPP, blockchain has a decentralized architecture that spreads the cost-bearing on a network. However, small suppliers can engage through federated consortia and public ledgers, avoiding centralized hosting bottlenecks (VeChain, 2023). On the other hand, the DPP regulatory certification and synchronization of such requirements unfairly affect SMEs beyond the EU, particularly those in the Global South. Without an international compliance support system, there is a risk that the DPP will be another form of regulatory colonialism, exacerbating the sustainability gap between high- and low-income production centers. Additionally, blockchain, with the ability to track the post-consumer product information, such as resale, repair, and reuse, provides an added advantage over other competitors in becoming circular. Social media like CircularID and VeChain have proved to support cradle-to-cradle systems by dynamically tracking and recording multiple lifecycles of the same product (CircularID, 2022). On the other hand, DPP mainly addresses cradle-to-grave compliance with very little consideration of post-consumer tracking. This restriction limits its capability of being a truly regenerative-design enabler, and blockchain systems streamline the emerging sustainability mechanisms, including resale incentives, automated carbon trees, and consumer repair certifications, integrated in real time.

A highly unexplored yet theoretically significant advantage of blockchain is democratized governance. In a truly exceptional way, blockchain-style systems allow multilateral involvement since non-governmental organizations, labor unions, and even consumers can verify transactions and highlight inconsistencies, as seen in the Bangladesh Cotton Blockchain Project (ILO, 2023). Digital Product Passport (DPP) has a technocratic approach to regulation whereby the participation of grassroots stakeholders is limited to institutional actors, customs authorities, and national regulators. Such an arrangement reduces the domain of local accountability and constrains sustainability discussion under the top-down, EU-centered domain. In addition, blockchain provides a relative strength in harmonizing trade across borders. Even though the jurisdiction of the DPP is limited to the confines of the European Union, the blockchain platforms can assist in bridging the different legal regimes because of their cryptographical neutrality. Despite GDPR compliance concerns, still present (especially immutability and the rights to erasure), hybrid modes are in development. These encompass the off-chain storage of sensitive personal information and on-chain hashes that prove the authenticity without breaching privacy (Kouhizadeh et al., 2021). This flexibility allows blockchain solutions to navigate highly convoluted global regulatory avenues more easily than the EU-based framework that the DPP provides.

Overall, as much as the DPP is a strong regulatory tool in achieving standardization of sustainability reporting in European markets, the blockchain platforms offer superior practicalities in verification, flexibility, multi-stakeholder inclusion, and global scale. An alternative to an externally imposed policy-based compliance is suggested by this study and informed by the resource-based view and institutional perspectives concerning a deeper, practice-based approach. The results support the fact that blockchain can provide sustainable behavioral change, systemic trust, and lifecycle accountability, which go beyond what the DPP can achieve.

Table 1: Summary Table: DPP vs Blockchain Transparency Models

Dimension	EU DPP	Blockchain-Based Model
Data Governance	Databases are centralized, susceptible to retroactive editing and manipulation (Lopes and Barata, 2024).	Records are immutable and secured cryptographically, and cannot be tampered after adding (Kumar T P and K P, 2025)
Data Verifiability	Highly dependent on third-party audits and corporate self-reporting, subject to compliance symbolically (Langley *et al.*, 2023).	Can be verified via smart contracts and distributed Verifiable through distributed agreements, lowers scope for greenwashing (Bhatt and Emdad, 2025).
Stakeholder Involvement	Limited (top-down)	High (multi-stakeholder, participatory)

SME Accessibility	Large burden of compliance on SMEs owing to stringent structures for reporting (Shee Weng, 2025).	Can be possibly integrated with cheap digital tools, but barriers to adoption persist (Al-Sulami *et al.*, 2024).
Circularity Support	Cradle-to-gate	Cradle-to-cradle
Global Scalability	Exclusive focus on EU Green Deal and eco-design for sustainable products (Haase *et al.*, 2025).	Foresees several frameworks including ESG, SDG and can be adapted globally (Parmentola *et al.*, 2022).
Greenwashing Prevention	Audits are manual and periodic, increasing risk of inconsistencies and delays (Shee Weng, 2025).	Automated and consistent audits through smart contracts (Rozario and Thomas, 2019).

As per the regulations of the European Union (EU), it has been indicated that the key objective of the DPP is to augment the sustainability of the clothing and textile sector, but on ground it would prove to be challenging to realize. At the outset, there is diversity within products that prevail in the industry as they tend to be different, often mirroring varied expectations from consumers regarding sustainability and durability. There is a need to customize DPP for every single product, while keeping in mind varied approaches, based on whether the apparel is of high value, functional or branded piece of clothing, or an apparel with low value addition. For products having low value, there is a high probability that DPP would be developed for a specific product series or batch (European Commission, 2024). At the same time, DPP has the potential to offer exclusivity to high-priced and niche apparels, linking it with a greater value-addition and a circular product lifecycle (Jæger and Myrold, 2023). Akin to the automotive or electronics sector, such kinds of products can be individually traced to know about their history, facilitating producers to provide product warranties and repair services for a lifetime. Recycling and categorization procedures for this type of end-of-life product could bring in clarity and render it easy to manage. Furthermore, it has also been noted that DPP could be instrumental in the development of a second-hand marketplace (Domskienė and Gaidule, 2024).

However, the DPP is just a framework and not a technology and thus requires technology for its implementation. DPP on its own as a framework has several shortcomings. For instance, from a global perspective, in supply chains that are digitally distributed, stakeholders tend to be located in remote places, functioning from several nations having varied legal and regulatory systems (Domskienė and Gaidule, 2024). A large variety of apparels are globally produced and sold within the global marketplace. As an outcome, product volumes in market circulation are very huge, and tracing them, and storing its information over extendable time periods is a task that cannot be conceived. From the perspective of producers, the intricate multi-stage supply chain comprises several procedures to convert materials into clothing, warranting the need for standardizing the required data. Similarly, irrespective of DPPs determination to augment sustainability and lower emission levels, choosing a technology is often a problem for producers, who have the onus of managing the requirement for sustainability (MacCarthy, Ahmed and Demirel, 2022).

Given the evolution occurring within the environment of supply chain transparency, it is evident that blockchain presents robust safeguards as compared to DPP. In contrast to DPPs which simply merge product details for traceability and compliance, blockchain has the proclivity for providing decentralized and immutable records which cannot be tampered, are secure cryptographically (Weller, 2024), rendering them extraordinarily resilient to manipulation or falsification. As per empirical research, it has been revealed that blockchain presents a distinct advantage in terms of traceability while preserving privacy and auditable, wherein all transactions can be verified through smart contracts and digital signatures. This not only ensures transparency but also trust over all phases of the supply chain (Sezer, Topal and Nuriyev, 2021). In addition, experimental studies that have been carried out in sectors that are analogous (construction) have indicated that blockchain could enhance completeness and information security by around 261%, as compared to other traditional digital systems (Sezer, Topal and Nuriyev, 2021).

Furthermore, the distributed ledger feature of blockchain facilitates collaboration and access to multi-stakeholders, which eliminates the necessity for having centralized authorities while lowering instances of information asymmetries, which is critical in disjointed settings such as fashion supply chains (Nwani, 2025). Though DPPs have been known to extend support to consumer engagement and circularity, they do not possess the features of resilience against forgery, in-built verifiability, and autonomous cross-system interoperability of blockchain (Nwani, 2025). Thus, it can be concluded that blockchain not just satiates institutional demands for authenticity and ESG rigor, but it also proactively strengthens it with auditability, trust, and strategic transparency.

2.9 Literature Gap

Although the number of scholarly and practical articles specifically investigating blockchain technologies as a form of ensuring more transparency in fashion supply chains has been increasing, gaps exist in the available academic and applied literature. These gaps manifest empirical grounds in the use of technology, organizational preparedness, clarity on regulations, and inclusion in sustainability change.

One significant gap is that limited rigorous empirical research studies measure the practical utilization of blockchain applications in fashion supply chains. Most available works deal with theoretical possibilities instead of measurable results. As an illustration of the cases mentioned above, the studies by Saberi et al. (2019); Treiblmaier (2019) argue that blockchain positively impacts traceability and transparency. Still, they do not provide quantitative data on several efficiencies, cost savings, and better adherence to ESG after implementation. Similarly, Ahmed and McCarthy (2021) highlight the concept of provenance tracking in fashion but provide only a few figures regarding the user adoption or ROI.

Such a constraint is of particular concern to SMEs in the Global South since resources there are stringent and so digital investments must be justified by evidence. Mohammad and Vargas (2022) criticize the vast majority of case studies that do not consider the assessment of scalability rates, cost-to-benefit ratios, and performance metrics, which denies decision-makers the chance to have coherent frameworks that allow them to determine the feasibility of investment. Enayati et al. (2024) provide confirming evidence as they demonstrate that a trial of moving blockchain at the scale of Indian artisan cooperatives could not be completed because of the absence of implementation statistics and support networks, rather than the defectiveness of technology itself. Follow-ups after deployment are still lacking, further curbing blockchain's perceived credibility as an agent of change.

The other gap deals with overemphasizing the technical architecture of blockchain: distributed ledgers, smart contracts, and consensus mechanisms, without going into the extent fashion firms need to adapt to its use. Despite the hundreds of articles on blockchain, many authors have unexplored how the change-management process, internal resistance, digital maturity, and cross-functional training can determine adoption success. Naradda Gamage et al. (2020) observe that SMEs usually do not have in-house IT units or organizational systems required to adopt blockchain instruments. Nevertheless, there is little discussion in the literature regarding how to overcome cultural inertia, redesign working processes, or internalize new governance practices by firms. The lack of this link is an obstacle to the emergence of specific context adoption models that fit the different environments of operations.

The existing research on the use of blockchain in financial and medical fields supports the advantage of strong sector-specific guidelines and interoperability rules. In comparison, the fashion industry has no overall shared approaches to integrating blockchain, particularly regarding ethical sourcing, worker protection, and environmental-related indicators. The Digital Product Passport (EPRS, 2024) is a step in the right direction, but at the same time not sufficient because it fails to suggest enforceable guidelines on the realization of traceability and ESG reporting using blockchain technology. This flurry of regulatory vacuum creates uncertainty in industry, especially among companies with a presence in more than one jurisdiction, on how to deploy blockchain systems so that future compliance needs could be achieved. In the absence of pervasively spread taxonomies and practices, companies may prove to be ad hoc in their implementation, could provide duplicative reporting, and auditing inconsistency. Marques et al. (2025) forewarn that blockchain can induce silos instead of doing away with ancient fragmentation, in the absence of harmonized standards.

The conflict between the concept of data immutability and user privacy remains underserved. The promise of blockchain to offer tamper-proof transparency is naturally incompatible with data protection regulations such as GDPR, particularly regarding the right to be forgotten under Article 17 (EU GDPR, 2018). Although Bodie (2022) has put the concept of zero-knowledge proofs to enhance privacy, in practice, designated cryptographic mechanisms have not yet been realized in the supply chain governance that is led by blockchain. Further, discussion on how sensitive data, like wage information or biometric data, of garment workers, can be anonymized, without undermining the auditability of the system, is relatively scarce. This prompts ethical questions, which are habitually overlooked in techno-centric books, damaging the confidence of stakeholders who are already afraid of being monitored in the digital world.

The literature on including blockchain has a serious loophole in addressing inclusivity that Calvo and Archer (2021); Bag et al. (2023) point out. Most researchers pay attention to large Western brands and suppliers that have reached their digital maturity and thus exclude Asian and African low-tier manufacturers, their goals, and difficulties. Blockchain is typically presented as a levelling mechanism but can be a source of the digital divide unless serious training, funding, and infrastructural investment are provided. The Indian (Enayati et al., 2024) and African (Teniola and Merlinda, 2024) case studies report that a lack of connectivity, vendor support, and a footprint of local blockchain-specific expertise are considerable adoption hindrances. Literature does not question the possibility that blockchain will support the power structures of global value chains instead of breaking them. This omission is detrimental to the SDG 12 recommendation of inclusive production systems and captures a serious literature gap.

Authors referring to the Institutional Theory (DiMaggio and Powell 1983; Treiblmaier 2019) demonstrate the theoretical capacity to explain patterns of adoption, but it is rare in existing blockchain in fashion research to consider extra theories that may enhance an understanding of more motifs to dynamic enactment, the development of sectoral expertise, or the battle among competing institutional regimes. This explanatory gap prevents the growth of robust predictive models and hinders cross-study comparison. In addition, most of the available literature lacks intersectional or socio-political analyzes, and issues of how blockchain technologies influence labor rights, gender equity, and regional discrepancies in the fashion supply chains have not been addressed. The result is serious blind spots when it comes to ethics.

At the same time, the current literature pays little attention to the long-term environmental and social effects of blockchain-based interventions. The literature does not indicate whether such systems support the desired behavioral change or increase performance after an extended period, since little to no such evidence is available in the literature (Ahmed 2025; James 2022). The lack of longitudinal studies or a methodical comparison across periods leaves the question concerning the role of blockchain in enhancing the long-term ESG compliance unanswered, and it may be replaced with the provision of a temporary reputational gain.

2.10 Summary of the Literature Review

This literature review critically analyzed the ability of blockchain to enhance transparency, traceability, and sustainability along fashion supply chains. The review traces the history of progressing technology from its inception as cryptocurrency to modern enterprise applications, highlighting the three fundamental aspects of its progress, including distributed ledgers, smart contracts, and cryptographic security. Practical use cases in illustrative case studies like IBM, Kaya & Kato, VeChain, and the Aura Blockchain Consortium currently target provenance tracking in circular-economy efforts like SDG 12 and automating ESG-compliance actions. The review will rely on the Institutional Theory and available ESG frameworks to determine the strategic importance of blockchain to organizational actors. Obstacles to implementation are, however, substantial. Technical barriers are scalability, integration complexity, and energy usage intensity constraints. Some organizational frictions that impede uptake include digital illiteracy and poor clarity of return on investment. System-related issues, especially poorly defined regulatory systems and widespread suspicion among stakeholders, make implementation difficult. Emerging market-based smaller firms and suppliers are still disproportionately excluded by the innovation ecosystem, and blockchain immutability still raises privacy concerns. The literature depicts the lack of empirical, long-term research studies and a comprehensive governance design.

Lastly, the chapter presents a critical comparative analysis of the European Union's Digital Product Passport (DPP) and blockchain-based transparency models to highlight regulatory, technical, and practical divergences in advancing supply chain transparency within the fashion sector. Conclusively, since blockchain has a transformative possibility, its use in fashion supply chains is decentralized and disjointed. Subsequent academic work needs to fill the gap between the technological potential and practices in operation, explicitly to be representative and empirically proven and clarified as to regulation, to render sustainable fashion supply chains.

CHAPTER III: METHODOLOGY

3.1 Introduction

The chapter provides methodological guidance toward examining the degree to which blockchain technology delivers greater transparency and traceability of fashion supply chains, underpinning sustainability requirements captured by the Sustainable Development Goals (SDGs), Environmental, Social, and Governance (ESG) criteria. Based on a pragmatic paradigm, the research uses a mixed-method research design to explore the observable results of blockchain implementation and determine the organizational and technological limiting factors that hinder the implementation process. The quantitative indicators obtained by fashion retail practitioners are merged with the qualitative information provided by blockchain and information-technology experts, and both underline the need for a comprehensive vision of technology and sustainability integration. This chapter discussed the philosophical assumptions regarding the research, the selected research design, the sampling strategy, project data-collection steps, the method of analysis, ethical issues, and the limitations associated with the methodology.

3.2 Research Philosophy and Paradigm

In the initial phase of any research study, researchers are confronted with the task of choosing a particular design that can be used for their research. There are several research designs in existence however, there is no simple system for classification that elucidates every variation that needs to be taken into account (Gaus, 2017). Several researchers think about their research while taking into account diverse techniques for data collection (for e.g., interviews, questionnaires), however as indicated through figure 20, this procedure is deemed to be at the crux of the research onion. Certainly, questions pertaining to the methods of research are of secondary significance to questions regarding the paradigm that can be applied in a particular research (Saunders, 2023).

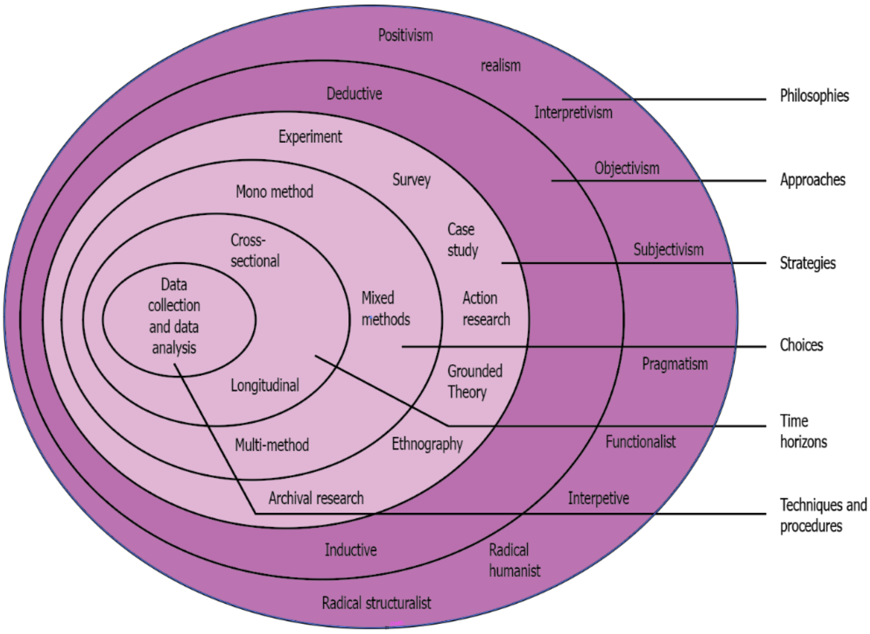

Figure 20: The Research Onion
Source: (Saunders, 2023)

A research philosophy shapes every subsequent decision in the study, guiding both the choice of methods and the subsequent interpretation of findings (Ali, 2024). This research is based on pragmatism philosophical assumptions. In the pragmatic paradigm, the current examination recognizes that no unique approach is adequate to explain the complex phenomenon of blockchain adoption within the global fashion supply chains. A pragmatic paradigm thus incorporates quantitative and qualitative methods and deploys objective data to supplement extensive stakeholder knowledge (Sim et al., 2024). This concurrent focus is vital when considering emerging technologies integrating technological systems and human decision-making processes.

Unlike positivism, which assumes objectivity and empirical tools, pragmatism entails comprehensive results and provides detailed answers to the research question. This orientation promotes the intentional use of various methodologies to capture a complicated matter completely (Ali, 2024). For example, Xiaohui's (2024) survey-based positivist inquiry into ESG measures in the textile industry in China could be considered. His work provides a strong statistical confirmation of its position, but he tends to overlook the cultural and organizational factors that affect adoption, which are common in positivist analysis. Although positivist designs are highly proficient in testing hypotheses, the designs fail to consider the context-specific conditions under which technological diffusion occurs within different environments (Sim et al., 2024).

Contrastingly, the strength of pragmatism would be the adaptability it offers, facilitating researchers to complementarily derive from both qualitative and quantitative techniques (Kaushik and Walsh, 2019). The flexibility thus offered by pragmatism allows for an enriched knowledge about phenomenon which is based on institutional concepts, human values, and social dynamics, which might not be possibly obtained with a statistical analysis on its own. With the integration of surveys and interviews, a research based on pragmatism could unravel the inspiration, viewpoints, and power relations that tend to impact results (Elgeddawy and Abouraia, 2024). This type of orientation is vital in not just overcoming the gap existing among practice and theory, but it also tends to produce results that are meaningful and actionable for various stakeholders who are engaged in intricate real-world problems.

The qualitative study of the blockchain traceability phenomenon in the Indian textile industry by Hsu (2024) presents important insights on the institutional and societal mediators of adoption. However, the results depend on case-specific regulatory frameworks, diverse infrastructures, and diverse stakeholder expectations, which caution against the drawbacks of entirely qualitative research. The more practical orientation, which combines qualitative and quantitative data from this study offers a broader perspective on exploring transnational and complicated phenomena. Exploring how and why blockchain supports supply chain transparency and aligns with SDG 12 and ESG objectives involves statistical quantification and an awareness of the organizational and cultural logistics that would enable or hinder adoption. Such integration is facilitated by a mixed-methods approach, based on pragmatic methodology as a means of triangulation to support findings and construct the deeper, multi-stratified explanations of the complexities of global fashion supply chains (Sim et al., 2024).

The current study followed an explanatory sequential mixed-methods research design, in which quantitative data collected before the qualitative investigation to clarify arising trends. This type of implementation helped to understand blockchain networks where numerical signals require examination of contextual integers. The quantitative data, valuable in pointing to adoption numbers, is complemented by the qualitative results, which uncover the driving forces and barriers to these trends. A recent mixed-methods study in a European-center focus by Chiarini and Kumar (2021) shows that the ESG compliance in Industry 4.0 conditions is a matter not only of automation but also of institutional support and people-centered decision-making related to integration.

The present study examines the role of blockchain in the fashion supply chains. An explanatory sequential mixed-methods design is utilized, which entails a quantitative stage identifying the adoption trajectories and a qualitative stage explaining and contextualizing the adoption trajectories. This sequential logic works well when analyzing socio-technical systems because numerical data may hide interpretive nuances (Shukla et al., 2023). Simultaneous mixed-methods designs interfere with clarity in analysis, but a sequential design allowed iterative discovery of results, which increases explanatory power. In addition to this, its structure is pragmatic as it contrasts objective measures with subjective observations. As the empirical studies in sustainable operations have revealed, the sequential mixed-methods design could adequately bring out institutional enablers and technological barriers (Abdul and Sohag, 2025). This method takes more time to complete, and it needs more coordination. Still, its potential to balance statistical generalization with contextual insights makes it a worthy strategy to accept in the current research.

Critics of pragmatism, such as Sim et al. (2024), argue that it lacks ontological clarity and compromise philosophical coherence. However, this study deliberately treats coherence not as adherence to a single worldview, but as alignment between purpose, method, and context. Through the integration and synthesis of functional insights from both paradigms, the study informs policy, practice, and theoretical advancement across the fashion-technology-sustainability nexus. In the end, adopting a pragmatic research paradigm function as a dual theoretical and strategic decision; it overcomes the limitations of positivism in comprehending social-technical transitions and the shortcomings of interpretivism in producing scalable and actionable findings. Bringing these paradigms together enables the research to systematically assess how blockchain can reconfigure an opaque and fragmented fashion supply chain into a transparent, sustainable, and ethically verifiable system, thereby staying relevant to on-the-ground practice and global policy debates.

Using the paradigm of pragmatism in this research is specifically appropriate for examining the role of blockchain technology in improving transparency in supply chains within the fashion sector as it accords priority to real-world results and practical solutions as compared to inflexible adherence to a single methodological position. The paradigm of pragmatism emphasizes the incorporation of quantitative as well as qualitative approaches to tackle intricate, practice oriented challenges (Creswell and Clark, 2023). Considering that blockchain makes an impact on diverse dimensions such as operational, technological, and sustainability-related, the use of pragmatism enables researchers to investigate not only measurable outcomes (transparency and traceability metrics) but also experiences of stakeholders (trust perceptions and accountability). Furthermore, pragmatism is in alignment with the applied nature of sustainability objectives, concentrating on resolving problems and actionable insights instead of simple theorizing (Morgan, 2014).

3.3 Research Design

This research study has been designed to tackle a multidimensional, interdisciplinary subject, the effectiveness of blockchain technology in bolstering transparency and traceability across fashion-supply chains, and the extent to which it aligns with sustainability benchmarks such as the Sustainable Development Goals (SDGs) and the Environmental, Social, and Governance (ESG) frameworks. Given the technology's intricate technological and socio-institutional nature, a mixed-methods design was selected and implemented through an explanatory sequential design. This design was deliberately chosen over other available research strategies due to its ability to bridge generalizable patterns with rich contextual insight, a dual capability that aligns directly with the study's objectives.

A mixed-methods framework allows a complex analysis that integrates both the quantitative and the qualitative depth. The design is especially appropriate to studies of emerging technologies, such as blockchain, where technical possibilities must be interpreted with organizational, regulatory, and ethical complexities (Seshadrinathan and Chandra, 2021). The quantitative part of the study investigates the supply chain professionals' evaluation of the impact of blockchain characteristics (traceability, immutability, and decentralization) on improving transparency and SDG 12 and ESG priorities alignment. The qualitative research phase then follows the institutional and contextual determinants of the adoption practices. This structure enables triangulation in response to what and why questions. Similar designs have been effectively applied in sustainability research of Meier et al. (2023), supporting this study's aim to generate empirically grounded, actionable insights into blockchain's integration within global fashion supply chains.

An explanatory sequential design in mixed-methods research, begins with quantitative analysis and follows with qualitative exploration to interpret and deepen the initial findings (Wipulanusat et al., 2020). This structure is particularly suited to the present study, which investigates blockchain's impact on transparency and traceability within complex, multi-tiered fashion supply chains. While quantitative data helps identify adoption trends, only subsequent qualitative inquiry can reveal how organizational culture, infrastructure readiness, or stakeholder priorities shape these patterns. This design enables insight into both broad outcomes and the nuanced conditions that drive them.

Adopting an explanatory sequential design allows the study to proceed systematically, first detecting patterns of blockchain adoption and, subsequently, contextualizing those patterns. The explanatory sequential design, in which additional, qualitative steps follow the longitudinal survey data, also requires careful synchronization; gaps in the initial quantitative phase may bias the further qualitative enquiry (Amadi, 2021). However, its adaptability inherent in the method makes it especially suitable when examining quickly evolving and fragmented industries like fashion (Pesqueira et al., 2025). This approach aligns with the present study's aim to move beyond adoption trends and uncover deeper institutional and strategic influences on blockchain implementation.

Strict adherence to quantitative designs, most often cross-sectional surveys or experiments with manipulation, would have limited the current research, since these designs answer the question of the what or the how frequently of adoption but not the why. Even though Abdul and Sohag (2025) estimated great metrics on the ESG adoption within the apparel industry of Bangladesh using a survey-based design, they could not explain the diverging adoption behavior between firms that happened in seemingly similar situations. This weakness marks one of the key limitations of quantitative procedures, which target the frequency and relationships between specific outcomes without following up with discernment. This led to adopting a mixed-methods design that was crucial in discovering successful blockchain adoption determinants within an organization, institution, and behavior.

In contrast, qualitative methodologies, such as grounded theory or phenomenological analyzes, yield a deeper and richer grasp, especially when investigating novel or under-explored issues. Henninger (2015) conducted an ethical exploration of traceability practices via interviews and a thematic analysis, uncovering insightful perspectives on consumer perceptions, yet failing to grasp wider industry dynamics or quantifiable effects, constraining its relevance for strategic decision-making. Nevertheless, these approaches offer little capacity for generalization. However, such methods lack generalizability and are unsuitable for testing theoretical models or measuring the strength of associations, both are essential for assessing the broader effectiveness of blockchain features in enhancing supply chain transparency.

Although the mixed-methods approach used in this study strategically combines the strengths of the quantitative and qualitative methods (explanatory sequential design). It facilitates generalized data gathering on a large range of industrial practitioners to determine the patterns and perceptions of adoption, and then a qualitative investigation that examines the context and organizational factors that explain the patterns in your research. This stepwise design contributes to construct validation and guarantees interpretative depth, increasing internal consistency and external generality (Walker et al., 2019). The explanatory sequential design offers more analytic clarity than parallel data collection found in concurrent mixed-methods designs, which are frequently vulnerable to superficial integrations. However, the design requires more time and coordination, and the efficacy of the second phase depends much on the clarity and the quality of the first phase. This strategy is especially applicable in the fashion industry, where supply chains are typically decentralized, with different technological maturity levels, and rising demands for transparency. Whereas the quantitative section determines the variation between organizational contexts, the qualitative section determines why blockchain adoption is uneven. According to Chang et al. (2020), there are considerable limitations on SMEs, including the digital infrastructure gap, that could better be unpacked by interviews than standardized surveys.

This research adopted a mixed-methods approach to facilitate an in-depth undertanding about how blockchain technology improved supply chain transparency within the fashion sector and at the same time aligning with SDG and ESG goals. The quantitative method facilitated the researcher to gather measurable data regarding blockchain adoption, transparency, and efficiency indicators which enabled an objective analysis of how it impacted sustainability performance. Qualitative method on the other hand, based on interviews were instrumental in collecting detailed perspective from the respondents, thereby providing inputs about practical challenges, strategies for implementation, and ethical aspects. Such a blend of both quantitative and qualitative methods was vital in reinforcing the validity of the findings by incorporating empirical evidence with experiential knowledge. Eventually, the use of mixed-methods allowed a highly holistic examination of the potential of blockchain to nurture accountability, traceability, and sustainable practices across global fashion supply chains.

Similar designs have been applied effectively in supply chain and technology-focused research. For example, Rakshit et al. (2025) utilized an explanatory sequential model to study the resilience of blockchain-integrated supply chains in North America. Their initial quantitative phase highlighted perceived benefits in transparency, but follow-up interviews uncovered institutional mistrust and data standardization issues that hampered adoption. The study by Malik (2022) on blockchain interoperability issues conducted in various industries is based on a mixed-methodology. It illustrates how regulatory fragmentation and lack of universal technical protocols appear more powerfully in qualitative accounts than quantitative survey-based responses. These results highlight the methodological appeal of explanatory sequential designs, allowing for the identification of macro-level trends and bringing socio-technical and regulatory frictions to context, which is particularly important in emergent and multi-stakeholder settings like blockchain in fashion supply chains.

In this explanatory sequential design, the qualitative stage depends on knowledge obtained during the previous quantitative stage and is a source of evidentiary rigor. The study's methodology directly answers a constant criticism of mixed-methods inquiry, namely that the qualitative and quantitative results gathered simultaneously tend to stay separate. In this context, the qualitative interviews are purposefully oriented on the anomalies, unexpected results, and prevailing trends identified in the survey results, such as increased perceptions of the value of blockchain in combination with rather low usage rates. Highlighting these disparities adds an interpretive layer that gives considerable depth and applicability to the theory and policy.

Research in supply chain and technology-driven spheres has demonstrated that study designs with comparable structures perform effectively. To illustrate, Rakshit et al. (2025) adopted an explanatory sequential strategy to evaluate the resilience of blockchain-integrated supply chains across North America. While the preliminary quantitative segment indicated perceptions of heightened transparency, later interviews uncovered institutional distrust and data-format hurdles that restricted broader adoption. Likewise, Malik (2022) assessed interoperability challenges across various industries through a mixed-methods approach. He found that regulatory fragmentation and incoherent technical protocols were more evident in the qualitative narratives than quantitative data. These inquiries highlight the strength of the explanatory sequential approach in illuminating overarching trends and situating the socio-technical and regulatory frictions that shape real-world outcomes. This method proves particularly useful for probing emergent, multi-stakeholder arenas such as blockchain within fashion supply chains.

Mixed-methods research requires increased time, interdisciplinary knowledge, and coordination, but outweighs these requirements by the ability to solve challenging and multi-dimensional research questions (Amadi, 2021). This research is interested in the functional utility of blockchain and the situational conditions limiting its adoption, both of which cannot be well served by a one-method approach. Solely quantitative data is not sufficient to reflect organizational and institutional factors that impact adoption, whereas qualitative techniques are not sufficient to have any empirical generalizability. Therefore, mixed-method explanatory sequential design offers a systematic solution to relating measurable patterns to further investigation, leading to methodological integrity and concluding in contextual and policy-based evaluations on how blockchain fosters transparency and sustainability in fashion supply chains.

3.4 Population and Sampling

The population for the quantitative phase comprises fashion retail professionals working in supply chain, sustainability, or digital transformation roles. These individuals occupy positions where operational execution meets strategic oversight, making them critically positioned to assess how blockchain features, immutability, decentralization, and traceability affect transparency and reporting. Their roles functionally align with the systems and governance mechanisms blockchain aims to optimize, including traceability platforms, ESG audits, and supplier accountability. Consequently, this population was not chosen arbitrarily but in direct response to the study's need to evaluate informed, practice-based assessments of blockchain interventions.

In the current study, the target population directly correlates with the first and fourth research questions: the exploration of the possibilities of blockchain to improve transparency along the supply chains and its ability to promote sustainability goals. This concurrence is supported in literature. Tian et al. (2025) asked ESG and compliance officers in the Chinese textile industry and defended their decision to survey them by the fact that their decision-making process depends on data. This way, Hughes et al. (2018) hired the fashion industry representatives within the United Kingdom logistics profession, highlighting their importance in integrating technologies and governance at the system level. These precedents support the applicability of operationally embedded professionals to review technological interventions like blockchain.

As a result, the research population considered both production areas, e.g., South Asia, and consumption regions, e.g., Europe, to reflect the globalization of fashion supply chains. This cross-regional strategy indicated the transnational application scope of blockchain and guaranteed to capture the diversity in regulation, culture, and infrastructure. The participants needed a position in the fashion industry concerning the supply chain, ESG, or digital systems, and they had to demonstrate a proven interest in the traceability practice. Such criteria earned the relevance and validity of the concept. Paudel (2024) supports the view that targeted inclusion ensures internal consistency and reduces interpretive bias in research that deals with new digital technology realms, as informed respondents tend to distort analytical clarity.

The qualitative phase selected another related group of respondents: blockchain and IT specialists with hands-on experience in implementing or consulting blockchain applications in supply chains. This sample includes solution architects, in-house digital leads, blockchain consultants, and system integrators. Unlike the operational population in stages one and two, respondents were chosen based on their technical skills and ability to interpret the institutional, infrastructural, and ethical variables that influence blockchain implementation. The second and third objectives of this research, which are identifying the barriers to adoption and the extraction of the implementation practices, are directly informed by their statements.

The methodological relevance of this population is validated in prior research. Majumdar and Sinha (2019) recruited blockchain developers and digital strategy leads to examine institutional bottlenecks in Indian textile firms, revealing technical and cultural resistance points invisible to operational staff. Similarly, Sutton et al. (2019) advocate expert sampling in technology research to access domain-specific understanding beyond user-level experience. This study followed such logic to ensure that the qualitative phase provided strategic and interpretive insights that surveys alone could not reveal. Participants were drawn from various industries and geographies to enhance contextual richness. This included those embedded within fashion firms and those advising across sectors. This dual perspective was essential to examine how internal organizational culture and external industry demands shape blockchain applications.

Saunders, (2023) states that techniques of sampling can be segregated into two types: probability or representative sampling and non-probability or judgmental sampling. Probability sampling refers to a technique where every member within a population stands an equal scope to be selected for research. The probability sampling technique is deemed as the most appropriate manner for ensuring that all units of sampling represent their population equally (Rahman *et al.*, 2022). The key objective of probability sampling (also known as random sampling) is to acquire a sample that represents the population from which it was derived. Using probability sampling does not indicate that every sample would be 100% representative of the population. Rather, it indicates that majority of the random samples would be closer to the population most times, and there is scope to determine the accuracy of probable sample. On the other hand, non-probability sample refers to a sampling technique where the probability of participants being chosen from the overall population is not known, and there is no possibility of addressing the research objectives or answer the research question which warrant statistical interpretations regarding the attributes of a population (Ahmed, 2024). In this scenario, there is scope to generalize the outcome for a population but not hinging on statistics, thus, this sampling technique is usually used when a case study strategy is adopted.

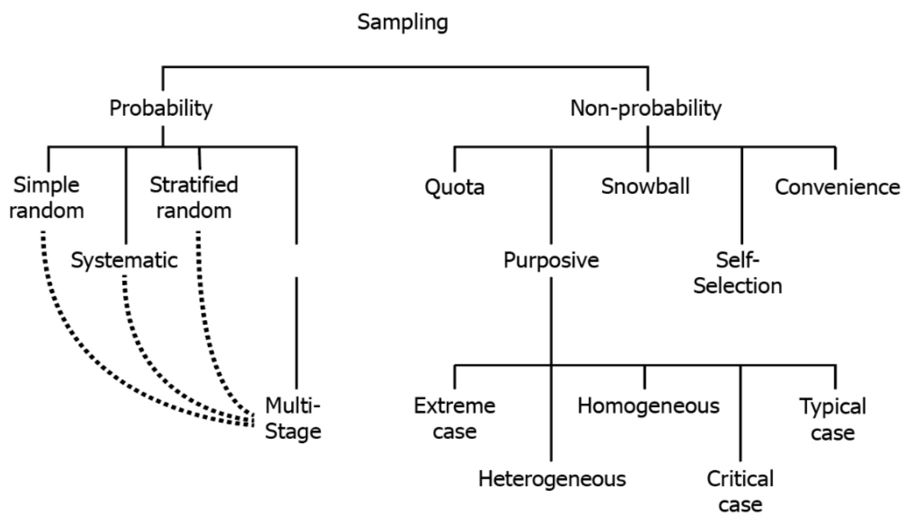

Figure 21: Sampling Techniques
Source: (Barzi, 2009)

Quantitative sampling embraces purposeful, probability sampling. Probability sampling is intrinsic in any quantitative research as it is instrumental in ensuring that all members within a population have an equal scope for being included in research, which improves the generalizability and representativeness of the findings obtained through research. Probability sampling also helps to eliminate any bias in sampling enables to arrive at rational statistical inferences regarding the wider population (Taherdoost, 2016). Sampling techniques including stratified sampling, simple random sampling, and cluster sampling offer a structured approach to choosing participants, which ensures a proportionate representation across the main categorical or demographic variables (Creswell and Creswell, 2018). The internal and external validity of a quantitative study is reinforced by depending on randomization, which renders the outcomes highly replicable and reliable. It is specifically of value in large-scale empirical research where objectivity, precision, and quantifiable associations are vital for testing hypotheses and model development. The lack of such a centralized database of fashion professionals involved in ESG sustainability and digital transformation roles was the first reason this approach could be followed to select participants whose roles explicitly concern the constructs that are the focus of the study. Purposive sampling sacrifices randomization to the concept of relevance, a compromise natural in exploratory research of technology where informed insights are essential (Casteel and Bridier, 2021). This decreases statistical generalizability but leads to construct validity and analytical relevance.

Purposive sampling was used for the qualitative element. Purposive sampling is significant as it enables efficient and targeted collection of research data from specific population samples that are pertinent to the objectives of the research. In contrast to probability sampling, purposive sampling does not need a complete frame for sampling, which renders it specifically useful within emerging domains, exploratory researches, and populations that cannot be easily reached (Etikan, 2016). From the context of applied research which could include sustainability practices or adoption of technology, a purposive sampling technique allows researchers to choose respondents with particular experience or knowledge, ensuring relevance and depth of insights instead of simple statistical representativeness.

The sample of 269 valid responses met the required minimum number of regression and cross-variable analyses (Boateng et al., 2018). Meanwhile, 269 samples were selected to allow the stratification of firms based on scale, geography, and blockchain maturity phases. Compared to traditional randomized styles, this purposive technique ensures that subgroups are conceptually and not statistically representative. Shukla et al. (2023) uses a similar strategy to study blockchain readiness in textile SMEs and target decision-makers who promote sustainability-oriented technological change. The recruitment material was selectively distributed using professional networks and ESG industry forums, which kept a sampling frame close to the thematic scope of the study.

Purposive sampling was used to recruit experts; 55 participants who proved to possess their blockchain skills were invited to participate. The study's practical use established selection criteria for participation, which required at least three years of work experience in blockchain-related work and at least one complete deployment within the range of supply chain attributes. These requirements meant that the participants had mastered the material itself and showed the capacity to apply it in the real world.

In the existing literature that explores emergent technologies, expert-based sampling has been widely used and critically evaluated, especially in measuring and evaluating complex innovations. Jeschke et al. (2021) state that such methodology is better to use in cases when it is impracticable to obtain comprehensive expertise, whereas Braun and Clarke (2021) note that a homogeneous sample of experts, usually 20-30 individuals, assist in achieving thematic saturation. The current research conforms to this suggestion, recruiting internal and external practitioners who can make a flexible exploration of blockchain adoption, both in technological viability and organizational lockout and stakeholder resistance.

To increase the external validity of the results, the sample was purposely planned to ensure high geographic and organizational diversity. Mackey et al. (2019) emphasizes the role of contextual and positional diversity in the expert sampling of the health-technology field, which supposes a parallel recommendation in the prospective blockchain research in the fashion industry. To enhance the methodological strength of the study, survey data were triangulated with the qualitative interview data, thus allowing the rigorous assessment of the convergence and divergence in the data.

The synthesis of rational and empirically based procedures allows the study to fulfill the stated goals by preserving scholarly strength. In addition, sampling processes were selected. The sample frame was pragmatically aligned because respondents with operational experience and technical authority were purposively recruited. These expert-based and purposive sampling processes achieved analytical validity and kept blockchain implementation's nuanced complexities in the fashion supply chains as objectives.

3.5 Data Collection Methods

The research integrated mixed-methods, sequential design to examine the role of blockchain technology in regulating transparency and sustainability in the fashion supply chain. The data were obtained through two successive stages, i.e., a quantitative survey and a supporting series of qualitative interviews. The entire process was supported by a well-developed digital infrastructure that enabled safe and productive collection and management of data.

The quantitative stage was formed by a web-based survey aimed at obtaining perceptions of blockchain by 269 professionals in the fashion supply chain. Moreover, these networks' fragmented and transnational character makes this approach more probable when using survey methodology to define the patterns and hypothesis testing (Aguinis et al., 2019). The questionnaire was organized around five thematic constructs, including perceived impact on transparency, ESG alignment, adoption readiness, implementation barriers, and blockchain awareness; each measured on a 5-point Likert scale, thus producing ordinal data amenable to inferential analyses like correlation analysis and regression. Such constructs were based on previously validated measures used in other studies conducted regarding the integration of ESG and the use of technology (Abdul and Sohag, 2025). Indeed, the celestial bifurcations of this reputed thematic partitioning were already there in the case of Shukla et al. (2023) when they sought to cover textile SMEs and their adoption of the digital environment.

To improve instrument validity, online distribution was to be used to reduce self-selection bias. To ensure this outcome, survey links were shared via sustainability forums and LinkedIn groups tailored to the industry, which Henninger (2018) found successful online. Although web-based surveys are prone to bias in responses, precautions including unique identifiers through user IP addresses were put in place to make sure each entry is unique and can be verified.

The second step involved 49 semi-structured interviews of experts working in blockchain applications in fashion supply chains. These interviews aimed to interpret survey results by giving them more meaning about barriers in adoption, implementation strategies, and regulatory gaps that do not align. The actors involved were internal stakeholders (e.g., sustainability managers, digital transformation leaders) and external actors such as blockchain consultants and tech vendors. The triangulation strategy reflects Sutton et al. (2019), who advocate involving technology providers and end-users in implementation research. Interviews had an organized structure in four thematic clusters of technical deployment, organizational governance, stakeholder coordination, and policy alignment, allowing the inclusion of depth but also resulting in consistency. The semi-structured format employed delicate discovery of localized issues or mismatch between the potential of blockchain and organizational preparedness, information that might not be covered in structured routes (Majumdar and Sinha, 2019). Encrypted video conference was used to conduct interviews, which were recorded or transcribed verbatim. The study followed ethical procedures, such as participants' consent, anonymization, and safe deposition. Analytical rigor and interpretive transparency were provided due to the observation of the six-phase approach to the thematic analysis (Braun and Clarke, 2021). The instrument's reliability was reinforced through two pilot interviews, which helped establish the flow of the interaction and clear questions (Mackey et al., 2019).

The successive collaboration between wide-scale surveys and contextually deep interviews delivered a holistic evaluation of the efficiency of blockchain in the fashion industry. This methodological approach is similar to that of Greenhalgh et al. (2018), who support sequential explanation frameworks for research investigations of emergent technologies in complex institutional settings. The research, therefore, provides a breadth and a depth-based evaluation of blockchain adoption within a solid technology and ethical platform by applying the survey and the interview, respectively.

3.6 Data Analysis Techniques

The SPSS (Statistical Package for the Social Sciences) was used to analyze quantitative results of the structured survey. This program was considered applicable due to its ability to handle large datasets and provide descriptive and inferential statistical analysis (Rahayu et al., 2024). The analysis began with descriptive analysis through frequencies, percentages and means to outline respondents' demographics, knowledge of blockchain, rating of traceability, immutability, and decentralization. The current descriptive examination is a first critical assessment of how stakeholders view the impact of blockchain technologies on supply chain transparency and sustainability.

Based on Pearson correlation, inferential exploration was implemented to ascertain the strength of association linkages between blockchain-enabled features and quantifiable improvements in the traceability or alignment with environmental, social, and governance (ESG) goals. The predictive ability of these blockchain features on transparency measures and the SDG/ESG compliance factors was then determined by subsequent multiple regression models.

The analytical architecture allows for the simultaneous evaluation of direct relationships and the control of confounding variables because most organizations may be large, geographically located, or have respondent functions (Chen et al., 2023).

The hypothesis-framework developed by the investigators in the current research was intentionally formulated to determine the degree to which blockchain-facilitated developments positively influence transparency and sustainability in modern fashion supply chains. Since the design was explanatory, the authors chose to use multiple regression, which was outlined by Chen et al. (2023), instead of simpler bivariate analysis to maintain the ability to account for interaction between variables and to individualize the contribution of each predictor. The reliability of the pretest was established through Cronbach's alpha, with values greater than the 0.70 limit set by Louangrath and Sutanapong (2018) in the social sciences. Therefore, this stability of measures is confirmed in the form of constructs described in the context of transparency perception and SDG relevance.

The study used a web-based questionnaire that was designed to take 10 to 15 minutes to complete. This design limitation was pre-determined to maximize clarity and minimize respondent fatigue. Based on empirical evidence, it was found that the completion rate was high, and the accuracy of the response was maintained. The concise, focused design chosen due to efficiency is a long-established procedure in the supply chain literature (Nilsson et al. 2018). Despite the rigor involved in the study, some limitations exist. Generalizability with purposive sampling is necessarily limited, and the perceived measures can only demonstrate a partial objectivity between firms and geographies (Casteel and Bridier 2021). Although these limitations suggest the inappropriacy of the analytic tools adopted, it is valid to note that they offered a legitimate test of hypothetical relationships, which could be further embedded in the context of the qualitative phase.

The qualitative aspect entailed conducting 55 semi-structured interviews with supply chain-related staff. Thematic analysis was utilized to analyze qualitative data because it is a qualitative methodological approach with inductive elements. This methodological design allowed a synchronicity relative to predetermined analytical categories based on extant literature, including stakeholder trust, ESG practices, and system compatibility. It allowed the emergent themes to come out of the data themselves. It was found that the choice of the thematic analysis was based on its flexibility and the ability to explain contextual and institutional complexity without strictly following theoretical framing (Braun and Clarke, 2021).

Two stages of coding qualitative data were performed. In the initial phase, deductively coded items were aligned with research goals and thus consistent with the prescribed line of analysis. Such codes focused on implementing blockchain into ESG reports, data governance frameworks, and organizational preparedness. The second step consisted of an inductive open-coding round to reveal further categories based on participants' experiences, such as regulatory ambiguity, operational inertia, and infrastructure limitations. This two-step coding process maximized both validity and flexibility in analysis. Deductive coding maintained a connection with the written objectives of research, but inductive exploration identified subtle barriers and facilitators that were not entirely expected during survey formulation. This duality in methods aligns with the pragmatic paradigm that the study employs, whereby the results do not ignore complexities in the real world.

Audio-recorded interviews were transcribed verbatim to maintain interpretive fidelity and contextual detail. Manual coding was applied, as the sample of interviews was rather small and the researcher was immersed in the topic continuously, which enabled profound interpretation. Compared with software-assisted analysis, the approach allowed for a prolonged relationship with the data and achieved thematic saturation (Saketkoo and Pauling, 2018). Braun and Clarke's (2021) six-step outline defined analytical procedures, thus leading to analytical transparency and internal coherence. Even though interpretation inherently entails subjectivity and bias in qualitative research, the risks of such possibilities were minimized with the help of a traceable coding process and a sample built according to similar themes. Contrary to the case studies or ethnographies, interviews provided comparative views across various organizational contexts, thus boosting the external relevance of the findings (Cote-Boileau et al., 2020). As a result, the approach provided a deep insight into the operationalization and resistance of blockchain technologies in the fashion supply chain industry.

3.7 Triangulation and Integration

In the present research, triangulation was found not only to serve as a validation method but also as a clearly deliberate means of creating explanatory breadth and methodological clarity within an explanatory sequential mixed-methods design. The research strategy aimed to find complementarity instead of data convergence, thus allowing qualitative data to explain and expand quantitative trends. Through triangulation, the researcher can overcome complexity and use several epistemic lenses, making the results more substantial and credible (Meydan and Akka, 2024).

At the design phase of the study, the determination was made that a qualitative component would logically precede the quantitative component. Through such sequencing, the researchers used survey results to draw semi-structured interview procedures aimed at the organizational, technological and institutional sides which influenced the stakeholders' view. Based on a connective triangulation approach, the survey-based patterns underwent expansion and refinement, using a qualitative phase. For example, statistical relationships between blockchain attributes and perceived transparency were contextualized through accounts of infrastructure limitations, regulatory ambiguity, and leadership attitudes. This approach ensured that the research addressed “what is happening” and “why it happens,” in line with the study’s core objectives.

When formulating the explanatory sequential framework, the integration process was carefully built into the formulation phase of the design to maintain methodological congruency. The qualitative dimension was not an addition to the quantitative, but a means of increasing the depth of explanation. The survey trends on the perceived usefulness of blockchain on traceability and ESG alignment were considered hypotheses that required exploration on interpretive issues. This is consistent with the connective triangulation model of Cornelissen (2023) in which one strand of identified data is used to inform another strategically. Instead of assuming congruence, the qualitative stage imposed the divergences as they wondered why the adoption of blockchain differed, despite the same level of infrastructure, by exploring the leadership practices, institutional norms, and regional differences. This deliberate ordering served the critical goal of the study to break into the superficiality of patterns and get into the organizational and systemic roots of blockchain performance within fashion supply chains.

Triangulation in the approach supported the current study because it intentionally overcame the methodological weaknesses of each data-gathering stage. Although giving statistical generalizability, a quantitative survey was limited in explaining institutional or stakeholder motivations. The qualitative interviews provided depth but lacked representativeness. Their complementary integration produced what Daniel et al. (2019) suggest as complementary validity, the strengths of one technique to offset the weaknesses of the other. This principle was operationalized using a weaving strategy in the analysis phase, where both data sets were simultaneously analyzed using similar thematic categories. As such, statistical evidence concerning ESG alignment was not directly addressed; interview-based narratives probed statistical evidence, revealing mediating factors, including organizational trust, compliance ambiguity, and uneven data governance. This overlap of inference contributed to the theme's accuracy and provided a stronger, context-situated description of blockchain uptake in diverse institutional contexts.

Finally, the study followed a triangulation of inference framework, which reinforced the reliability of its results by sourcing data through multiple outlets instead of employing one methodological framework (Sridharan, 2020). Such triangulation increased the credibility and relevance of the research, especially in a relatively new field like blockchain, where industry standards are dynamic. Therefore, the multifaceted ideas of transparency, sustainability, and operational preparedness in the environment of a fashion supply chain were reflected in fine-grained actionable information.

3.8 Ethical Considerations

The strong ethical aspect of the current study focused on individuals with diverse professional experience whose opinions related to a controversial and highly relevant topic: technological preparedness, management, and sustainable actions. Institutional ethics informed methodological procedures, qualified by the British Educational Research Association (BERA, 2018) and General Data Protection Regulation (GDPR), which regulates data protection and participant rights.

The major ethical principle that supported the research was informed consent. When distributing the survey, the respondents were presented with in-depth informational sheets that described the study's aims, emphasized the voluntary nature of the participation, and outlined how their information would be used. Informed participation was verified by the written signature of the survey respondent and the oral or written consent of the interviewee who used Zoom or Microsoft Teams. Such a two-consent strategy aimed at fulfilling ethical considerations in an online environment, where the lack of face-to-face interaction can result in disconnection or misunderstanding among the participants (Carter et al., 2021). The consent forms also state that the participants had the right to withdraw at any time they wished, without any reason, to offset the power bias that usually exists in research where industrial professionals are involved (Reid et al., 2018).

Highlighting the importance of anonymity and confidentiality, the study addressed organizational phenomena, issues of governance, and barriers to blockchain adoption. Thus, transcription was used to remove recognizable data like name, job title, and company affiliation to protect their organizational reputations. Internal markers assigned to participants were codes and pseudonyms. These steps align with the recommendations of Kaplan et al. (2022) regarding the depersonalization applicable in managerial and strategic inquiries.

All data was processed within the GDPR standards: it was encrypted and stored at password-protected university servers. After the transcription was over, the original audio recordings were deleted. When survey information was collected, it was anonymized and destroyed as soon as the analysis was completed. Such actions allowed controlling the legality, fairness, and transparency of data processing, so the three main GDPR principles, data minimization, data limitation of purposes, and data storage limitation, were met (GDPR, 2018).

When applying a mixed-methods design, ethical implications relating to the analytical part of the research required additional attention. Ethical risk was also low because the quantitative aspect used the techniques of anonymization and a highly structured, non-obtrusive survey. On the other hand, the qualitative part involved a higher level of ethical sensitivity, as thematic analysis is interpretive. The researcher might unintentionally distort participants' stories or make generalizations based on insufficient data (Lim, 2024). To minimize these risks, the researcher followed Braun and Clarke (2021) on being transparent and reflexive, making sure, in this way, the interpretations were based on the data. They shared its initial meaning as conveyed by the participants.

Secondly, professional integrity and the dignity of the participants were significant factors. Because blockchain application is a contentious and uneven process throughout the fashion industry, some interviewees were worried about publicizing criticism of their institutions. To deal with this, the interview guide was tailored to address those systemic obstacles and overall industry trends rather than pressurize the person or internally disclose information. This framing fostered open communication and minimized the likelihood of professional vulnerability or awkwardness.

The semi-structured formats also enabled the participants to control the direction of the discussion, providing independence and autonomy.

Another ethical aspect was added to the research design, i.e., equity and inclusivity. In this regard, the sampling strategy included recruiting participants across different regions, including Europe, South Asia, and East Africa, thus equating to the internationalized nature of supply chains in the fashion industry. This sustaining disposition introduced analytical depth and established the moral imperative to articulate diverse opinions, particularly those deriving from low-resourced environments often disregarded in technology-led exploration (Chang, Iakovou, and Shi, 2020).

The researcher received intensive ethics training and attained formal university review board approval before data collection relevant to the research. This approval process came with another important lens in ensuring that all processes met current ethical rules regulating research on human subjects. Overall, ethical aspects were incorporated within all stages of the study, including subject recruitment and data interpretation. Through an appreciation of ethical consciousness at every level of the design, implementation, and analysis process, the study has maintained methodological integrity, upheld the participants' protection, and rendered transparency of its results.

3.9 Limitations of the Methodology

Even though the explanatory sequential mixed-methods design utilized was methodologically sound, a number of the limitations need to be considered to ideally encompass the dimensions of the study findings. The selection criteria used during the survey and interview stages were non-probability and purposive respectively, limiting the generalizability. Although this strategy increases the relevance of the participants, as they appeal to informed stakeholders, it also risks leaving out the less visible actors, particularly underrepresented bodies or smaller businesses (Casteel and Bridier, 2021). Due to the high heterogeneity in global fashion supply chains, these omissions can reduce the validity of observed patterns.

The quantitative phase relied on self-reported data concerning blockchain's role in transparency and sustainability. Such perceptual measures, though useful for gauging stakeholder attitudes, are vulnerable to social desirability bias and variation in interpretation (Hinojosa et al., 2019). Constructs like “ESG alignment” or “traceability” may be understood differently across respondents depending on organizational maturity or regional regulatory exposure, complicating the comparability of responses. While Cronbach's alpha was used to assess internal consistency, such tools cannot fully eliminate conceptual ambiguity.

In the qualitative component, thematic analysis depended on manual coding, which carries the inherent risk of interpretive bias. As Braun and Clarke (2021) caution, the researcher's positionality may influence data interpretation, even with structured coding frameworks. Although coding followed an established theoretical logic, the absence of inter-coder validation could affect the consistency of theme identification. Additionally, the sequential nature of the design means the second phase is constrained by the insights of the first. If the quantitative stage omits key concerns, qualitative exploration may remain limited, a risk noted in sequential research by McClam et al. (2025). These limitations were carefully considered during design and analysis to preserve the study's credibility and relevance.

3.10 Chapter Summary

This chapter outlined the methodological framework adopted to examine how blockchain technology enhances transparency and traceability in fashion supply chains while aligning with SDG and ESG goals. Grounded in a pragmatic paradigm, the study employed an explanatory sequential mixed-methods design to generate both breadth and depth of understanding. Quantitative data from 269 surveys provided measurable patterns on blockchain perceptions, while 55 semi-structured interviews contextualized these findings within organizational realities. Sampling was purposive and stratified to ensure relevance and diversity. Data analysis combined statistical techniques (descriptive stats, Pearson's correlation, regression) with thematic coding to derive integrated insights. Ethical considerations, including informed consent, confidentiality, and GDPR compliance, were rigorously maintained. While the methodology provided robust, triangulated insights, limitations such as sampling bias and interpretive subjectivity were acknowledged. Overall, the approach offers a credible, multi-layered foundation for the study's analytical findings.

CHAPTER IV: RESULTS

4.1 Introduction

The current chapter integrates the empirical results with a mixed-methods research design, where quantitative and qualitative data are integrated to achieve statistical generalizability and provide contextual richness. The results are categorized into two significant parts: quantitative and qualitative. The quantitative strand relies on the answers to the survey among the professionals who are practitioners working in sourcing, manufacturing, logistics, and compliance as parts of the fashion supply chain. The survey tool captured five constructs linked to blockchain, including Blockchain Traceability Capability (BTC), Blockchain Data Immutability (BDI), Smart Contract Automation (SCA), Stakeholder Data Accessibility (SDA), and Supply Chain Transparency (SCT). Statistical research on these constructs used the theoretical tools of institutional theory and the resource-based view (RBV) in frequency distribution, descriptive statistics, Cronbach's alpha reliability measure, Pearson correlation, and multiple regression. The hypothesized relationships between blockchain capabilities and transparency perceptions were assessed in quantitative analysis. An accompanying qualitative analysis using semi-structured interviews with brand executives, technology providers and policy advocates to capture subjective reflections and organizational dynamics of blockchain adoption. Lastly, a thematic analysis determined drivers, barriers, ESG compliance demands, trustworthy stakeholders, and technological preparedness as prominent threads.

4.2 Quantitative Analysis

4.2.1 Frequency Analysis

Participant Current Job Role

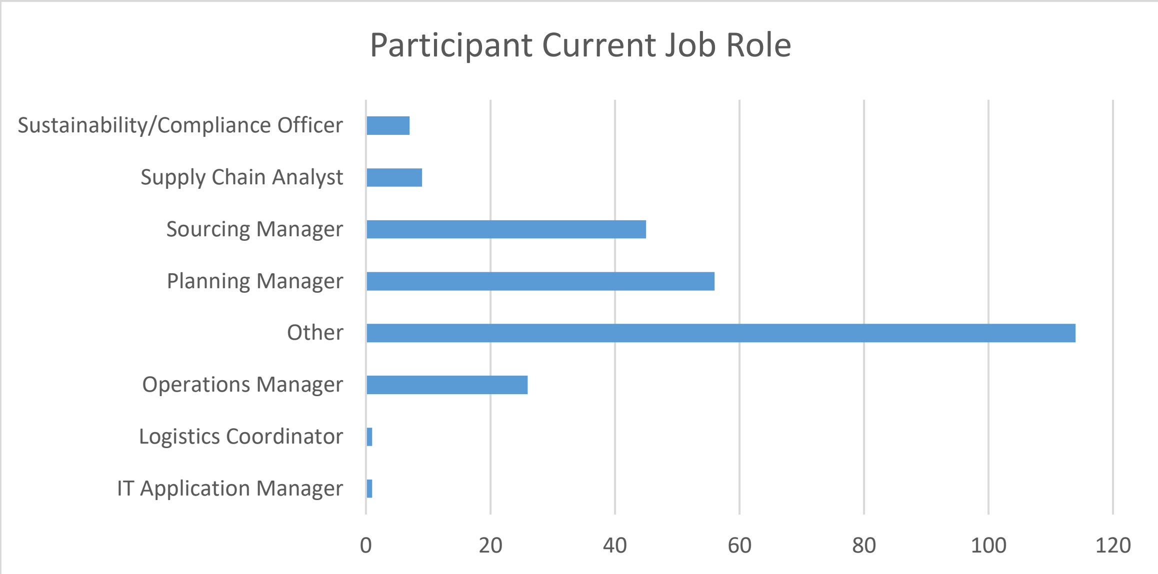

Figure 22: Participant Current Job Role

The frequency analysis of participant job roles in Figure 22 reveals that the majority (114) selected "Other," indicating a wide range of diverse positions not predefined in the survey. Among specified roles, "Planning Manager" (56) and "Sourcing Manager" (45) were the most common, followed by "Operations Manager" (26). Roles like "Supply Chain Analyst" (9), "Sustainability/Compliance Officer" (7), "IT Application Manager" (1), and "Logistics Coordinator" (1) were less represented, suggesting lower involvement or limited relevance in blockchain-related decision-making.

Table 2: Participant Current Job Role

Participant Current Job Role	Count of Participant Current Job Role
IT Application Manager	1
Logistics Coordinator	1
Operations Manager	26
Other	114
Planning Manager	56
Sourcing Manager	45
Supply Chain Analyst	9
Sustainability/Compliance Officer	7

Year of Experience in the Fashion Supply Chain Industry

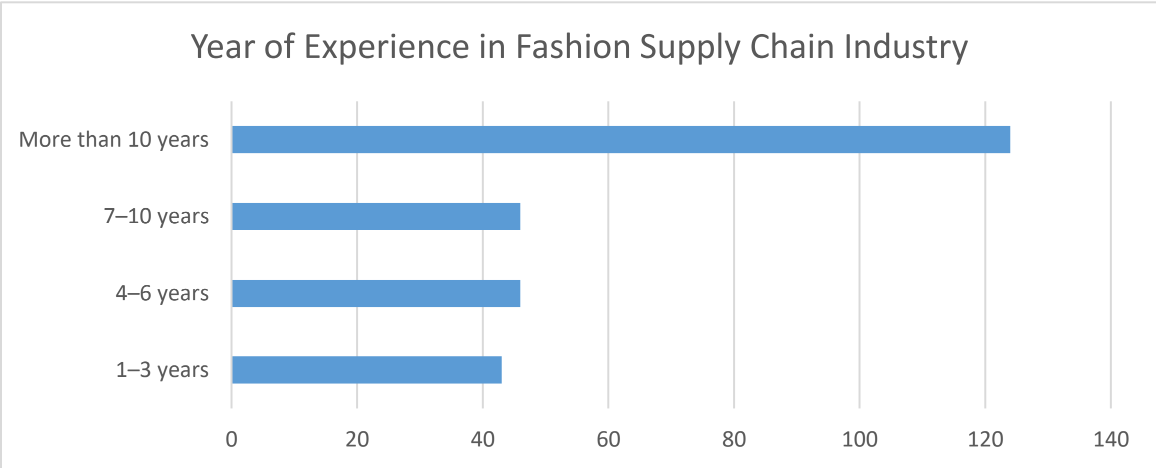

Figure 23: Participant's Year of Experience in the Fashion Supply Chain Industry

The data shows a strong representation of experienced professionals, with 124 participants (over 50%) having more than 10 years of industry experience in the fashion supply chain. Mid-career professionals with 4–10 years of experience make up a combined 92 responses, while early-career professionals (1–3 years) account for 43 responses. This indicates that the sample comprises knowledgeable and seasoned individuals, enhancing the credibility and reliability of insights gathered regarding blockchain awareness and adoption in the sector.

Table 3: Participant's Year of Experience in the Fashion Supply Chain Industry

Participant's Year of Experience in the Fashion Supply Chain Industry	Count of Participants' Year of Experience in the Fashion Supply Chain Industry
1–3 years	43

4–6 years	46
7–10 years	46
More than 10 years	124

Participant's Working Department

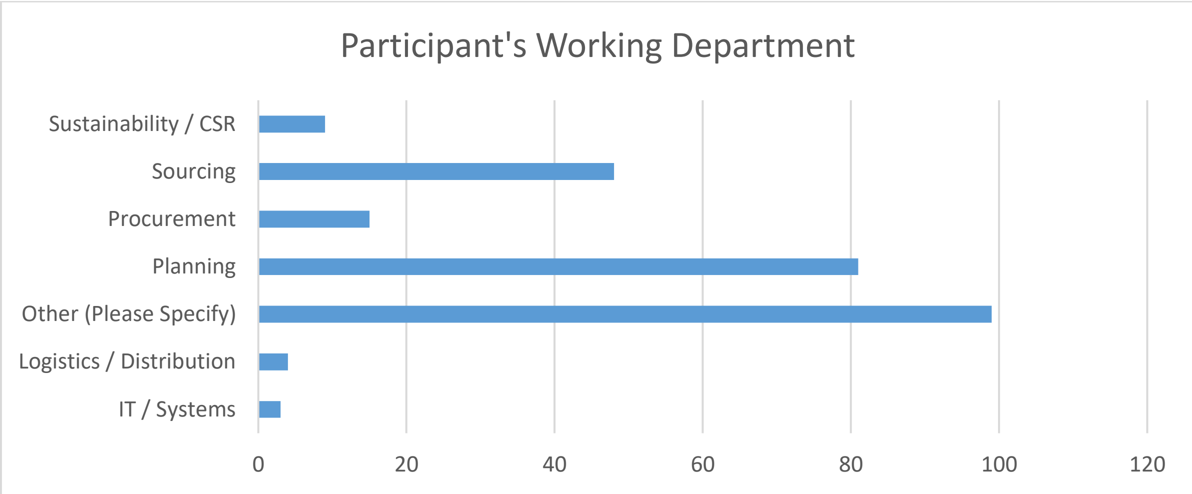

Figure 24: Participant's Working Department

The most significant proportion of respondents (99) selected "Other," suggesting the involvement of multidisciplinary or non-traditional departments in the fashion supply chain. Planning (81) and Sourcing (48) are the next most prominent, reflecting their central role in operational and procurement processes. Procurement (15), Sustainability/CSR (9), IT/Systems (3), and Logistics/Distribution (4) were less represented, suggesting that technology and sustainability teams may still play a limited role or are underrepresented in blockchain discussions within many fashion companies.

Table 4: Participant's Working Department

Participant's Working Department	Count of Participants' Working Department
IT / Systems	3
Logistics / Distribution	4
Other (Please Specify)	99
Planning	81
Procurement	15
Sourcing	48
Sustainability / CSR	9

Size of The Fashion Company Participant Works For

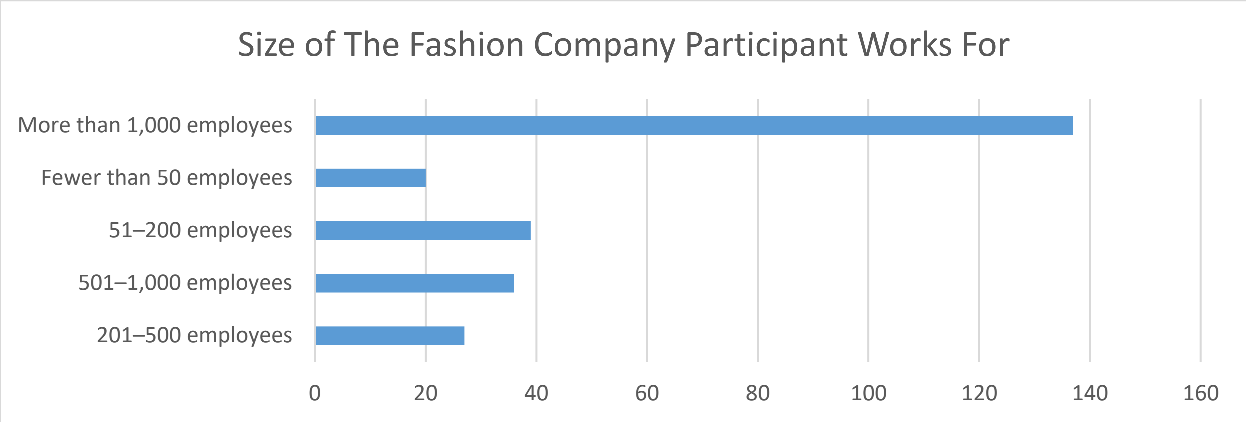

Figure 25: Size of The Fashion Company Participant Works For

Most respondents (137) work in large fashion companies with over 1,000 employees, indicating that blockchain interest or awareness may be higher among well-established firms. Medium-sized enterprises (51–1,000 employees) comprise 102 responses, while small businesses (fewer than 50 employees) represent only 20 responses. This distribution implies that larger companies may be better positioned or more interested in exploring digital supply chain innovations such as blockchain. At the same time, smaller firms may face constraints in adoption due to limited resources or digital maturity.

Table 5: Size of The Fashion Company Participant Works For

Size of The Fashion Company Participant Works For	Count of the Size of The Fashion Company Participant Works For
201–500 employees	27
501–1,000 employees	36
51–200 employees	39
Fewer than 50 employees	20
More than 1,000 employees	137

Region of Participant's Company Primarily Operates in

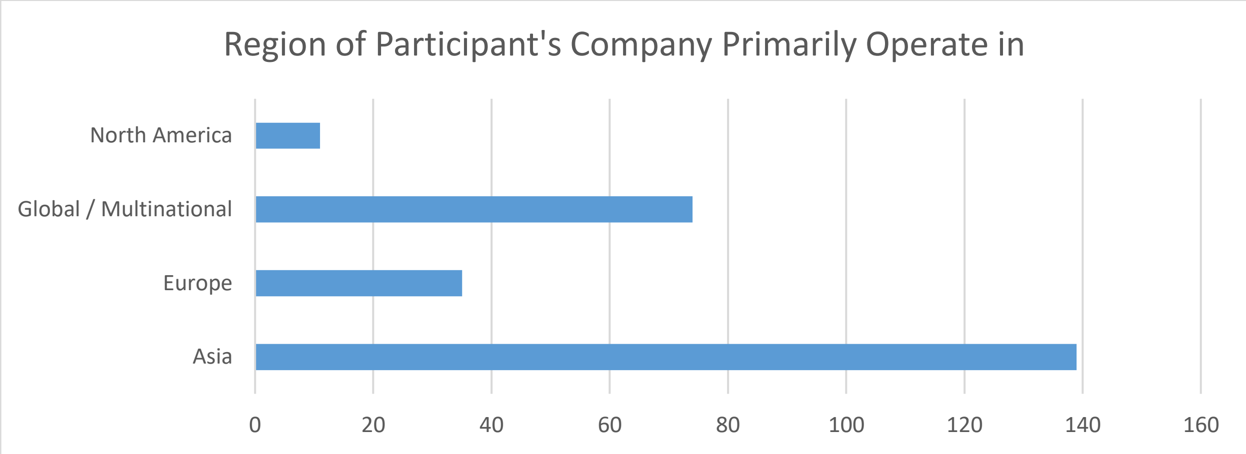

Figure 26: Region of Participant's Company Primarily Operates in

A substantial portion of companies represented in the survey operate primarily in Asia (139), followed by global/multinational firms (74), Europe (35), and North America (11). The dominance of Asian operations reflects the region's significant role in garment manufacturing and export, making it a critical context for studying blockchain's potential in improving transparency. The presence of global and European participants adds diversity to the dataset, allowing for cross-regional insights into digital adoption, supply chain ethics, and sustainability challenges.

Table 6: Region of Participant's Company Primarily Operates in

Region of Participant's Company Primarily Operates in	**Count of the Region in which the Participant's Company Primarily Operates**
Asia	139
Europe	35
Global / Multinational	74
North America	11

Do You Know What Blockchain Is?

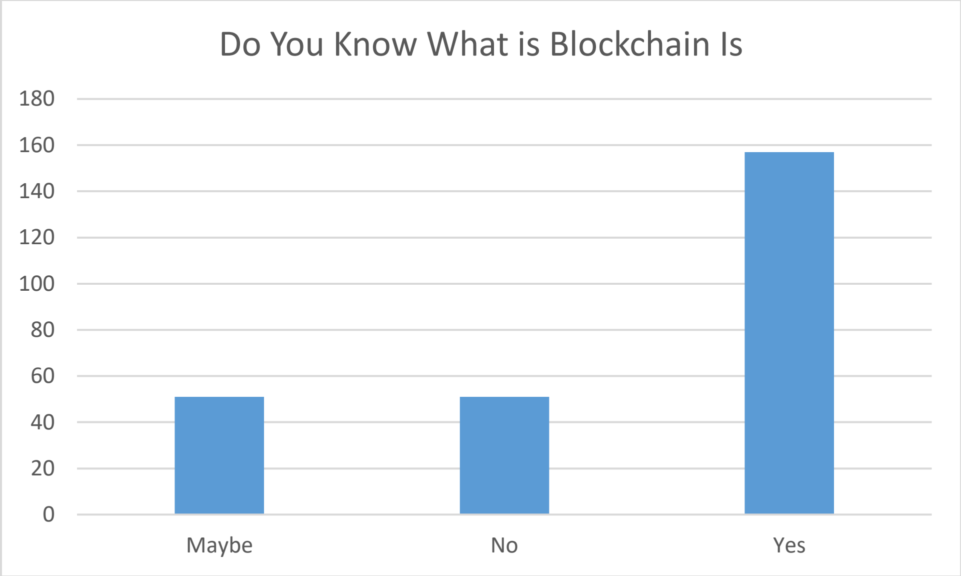

Figure 27: Do You Know What Blockchain Is?

Of all participants, 157 confirmed that they know what blockchain is, while 51 responded "Maybe", and another 51 said "No." This suggests a generally high level of awareness (over 60%), which is essential for meaningful adoption discussions. However, 102 participants with limited or no blockchain knowledge underscore a critical education gap. This indicates that awareness campaigns and targeted training are necessary, especially if blockchain is to be adopted across all operational tiers within fashion supply chains.

Table 7: Do You Know What Blockchain Is?

Do You Know What Blockchain Is	**Count of Do You Know What Blockchain Is**
Maybe	51
No	51
Yes	157

Do You Use Blockchain in Your Work?

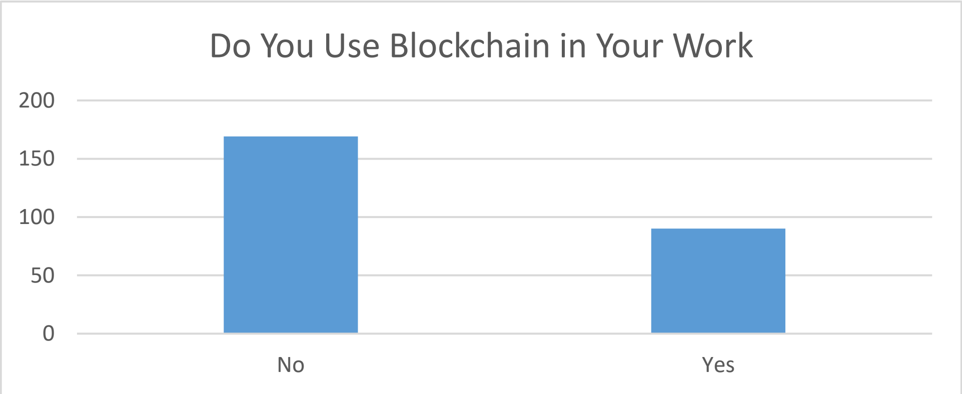

Figure 28: Do You Use Blockchain in Your Work?

In spite of reasonable awareness levels, only 90 participants indicated that they actively use blockchain in their work, compared to 169 who do not. This stark contrast highlights a significant implementation gap between theoretical awareness and practical usage. It suggests that while blockchain's benefits are increasingly understood, barriers such as cost, integration difficulty, or lack of stakeholder buy-in continue to prevent widespread adoption. This insight underscores the need for strategic interventions to translate blockchain knowledge into actionable, operational practices within the fashion industry.

Table 8: Do You Use Blockchain in Your Work?

Do You Use Blockchain in Your Work	**Count of Do You Use Blockchain in Your Work**
No	169
Yes	90

4.2.2 Descriptive Analysis

Table 9: Descriptive Statistics

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Blockchain Traceability Capability	259	1.0	5.0	4.036	.7460
Blockchain Data Immutability	259	1.0	5.0	3.933	.7347
Smart Contract Automation	259	1.0	5.0	3.900	.7295
Stakeholder Data Accessibility	259	1.0	5.0	3.952	.7493
Supply Chain	259	1.0	5.0	3.964	.7303

Transparency	
Valid N (listwise)	259

The descriptive analysis can assess stakeholders' views on basic blockchain operations in fashion supply chains. They were measured using 5-point Likert scoring, which statistically evaluated traceability, immutability, automation, data accessibility, and transparency. The analysis generates early-stage evidence on stakeholders' confidence in blockchain-enabled operations.

The highest mean is the one that refers to traceability, which shows that the participants agree with the technological ability to provide traceability within fashion supply nets, mainly. This agreement concurs with the latest academic opinion, where traceability is regarded as one of the most prominent blockchain advantages (Saberi et al., 2019). The comparatively small standard deviation (0.746) supports the point that the deviations of the respondent judgments are minimal. Traceability is critical in the fashion industry as the market is multi-layered. As a result, the authenticity of raw materials' origin and working conditions is difficult to verify (Ahmed and McCarthy, 2021). These findings are supported by the practice of LVMH and H&M introducing blockchain-enabled QR codes and digital passports, allowing consumers to check whether the product was manufactured sustainably and whether or not its provenance may be verified by a firm (Aura Blockchain Consortium, 2024). Combined, the results highlight a high degree of stakeholder trust in the ability of blockchain to trace a given asset.

The participants' average value given to immutability was 3.933, which is also an essential technical feature of distributed ledgers. Although this score shows the overall faith in the tamper-proof design of blockchain, it is still lower than the average traceability. The difference could be due to implementation difficulties or even fewer misunderstandings about data retention, especially when it comes to permissioned systems, where high-level administrative policies may undermine the utopian durability. The regulatory tensions, like the contrast between the persistence nature of blockchain and the right to be forgotten in the GDPR, can also cause low ethical and legal confidence (Thilakavathy et al., 2023). The average mark on intelligent contract automation was 3.900, which indicates moderate disagreement with the demand for the described functionality. The smart contracts are self-executing code allowing pre-prepared sequels, including facilitating payment or ESG compliance (Hasan et al., 2019). In the fashion industry context, the tools may be utilized to simplify the process of wage transfer or ensure that sustainable manufacturing is taking place, reducing the likelihood of human mistakes and simplifying manual management. Reasonable stability of stakeholders is manifested in the slight standard deviation of the stakeholder group (0.7295), which indicates a good understanding of the potential of smart contracts, but the attained average value is slightly lower, which suggests that there are still obstacles, such as the complexity of code, the proportion of legacy systems, and insufficient preparation in organizations (Loots, 2023).

The average score of stakeholders on data accessibility was 3.952, which is a sign of general consent of the opinion that blockchain positively affects data access in fragmented supply chains. Real-time availability of information across tiers has become vital in coordination, risk management and compliance. Literature purports that the shared ledger architecture of blockchain leads to access to a single source of truth that is shared by multiple parties and relieves data silos (Vadgama et al., 2019). This enhances supplier-to-supplier, supplier-to-logistics, supplier-to-compliance, and supplier-to-brand cooperation. However, the reduced average implies that there are still barriers to entry, especially among low-tier suppliers and SMEs in the Global South, which might restrict a complete entry into the market (Calvao and Archer, 2021).

The average of 3.964 indicates the solid approval of the role of blockchain in supply chain transparency. In this regard, the term is the ability to track processes, certifications, and raw materials back to the retail outlet. The decentralized structure of blockchain and its ability to capture real-time data qualify it to be deployed to fix the opacity issue surrounding the global networks of fashion, which is most relevant when it comes to increasing consumer activism and strict ESG demands (UNEP, 2025). However, the variation in standard deviation identifies tiny variances, which may be associated with organizational extent, digital progress, or the absence of earlier investments in a traceability tool.

4.2.3 Reliability Analysis

Scale: BTC

Table 10: Reliability analysis BTC

Reliability Statistics	
Cronbach’s Alpha	N of Items
.912	5

The BTC scale demonstrates excellent internal consistency with a Cronbach's Alpha of 0.912, exceeding the commonly accepted threshold of 0.90 for high reliability. This indicates that the five items used to measure blockchain's role in traceability within fashion supply chains are highly correlated and consistently capture the same underlying construct. High reliability is crucial for traceability, as it reflects confidence in the respondents' ability to evaluate blockchain's impact on monitoring product origin, ethical sourcing, and compliance documentation. Since traceability is a critical application in fashion supply chains, the strong reliability score further validates the robustness of the BTC measurement scale in reflecting real-world perceptions.

Scale: BDI

Table 11: Reliability analysis BDI

Reliability Statistics	
Cronbach's Alpha	N of Items
.872	5

The BDI scale reflects strong internal consistency with a Cronbach's Alpha of 0.872, well above the acceptable threshold of 0.70 (George and Mallery, 2003). This suggests that the five items measuring data immutability through blockchain form a coherent and reliable set. Immutability, meaning blockchain records' unalterable and tamper-proof nature, is central to its adoption in compliance-heavy industries such as fashion (Politou et al., 2019). The high reliability confirms that respondents had a stable understanding of this feature, enabling accurate measurement. This is especially significant for monitoring authenticity in sustainability disclosures and preventing retroactive falsification—key concerns raised by regulators and ethical watchdogs (Gariba et al., 2024). Thus, the BDI scale is suitably reliable for future analysis.

Scale: SCA

Table 12: Reliability analysis SCA

Reliability Statistics	
Cronbach's Alpha	N of Items
.892	5

The SCA scale yielded a Cronbach's Alpha of 0.892, indicating high internal consistency. Smart contracts are programmable scripts that self-execute actions based on set conditions, such as payment approvals or compliance triggers (Hasan et al., 2019). The strong reliability score suggests that the five items in this scale effectively capture respondents' perceptions of smart contract efficiency and their applicability within supply chain automation. The result supports that participants recognised blockchain's potential to automate operational processes, such as shipment tracking, payment release, and ESG condition enforcement without third-party intervention. This reliability is crucial, as automation is a cornerstone of blockchain's value proposition in operational transformation. The high alpha affirms the trustworthiness of the SCA measurement tool for broader inferential analysis.

Scale: SDA

Table 13: Reliability analysis SDA

Reliability Statistics	
Cronbach's Alpha	N of Items
.900	5

The SDA scale achieved an Alpha of 0.900, signifying excellent reliability. This indicates that all five items used to measure perceptions of data accessibility across stakeholders (e.g., suppliers, regulators, NGOs) were consistent and interrelated. In the fashion supply chain, data accessibility ensures real-time visibility and multi-party collaboration, which blockchain aims to deliver through its decentralized ledgers (Vadgama et al., 2019). The high Alpha score validates that respondents understood and uniformly rated the concept. This is particularly important as upstream and downstream accessibility remains challenging in traditional systems. The result strengthens the argument that blockchain can democratize data access in fragmented fashion networks and confirms that the SDA scale is dependable for further statistical modelling and comparison.

Scale: SCT

Table 14: Reliability analysis SCT

Reliability Statistics

Cronbach's Alpha	N of Items
.898	5

The SCT scale reports a high Cronbach's Alpha of 0.898, indicating robust internal consistency among the five items measuring blockchain-enabled supply chain transparency. Transparency involves open, verifiable documentation of product movement, sourcing, and ethical compliance—key concerns in the fashion industry (Ahmed and McCarthy, 2021). The reliability score suggests that respondents consistently viewed blockchain as a valuable tool for enhancing this visibility. This is particularly relevant given increasing regulatory requirements such as the EU's Corporate Sustainability Due Diligence Directive (European Commission, 2024). The nearly excellent reliability score confirms that the scale captures perceptions accurately and consistently. It also ensures that the SCT scale can be used confidently in regression analysis or further hypothesis testing involving transparency-related blockchain capabilities.

4.2.4 Correlation Analysis

Table 15: Correlation analysis

Correlations						
		Blockchain Traceability Capability	Blockchain Data Immutability	Smart Contract Automation	Stakeholder Data Accessibility	Supply Chain Transparency
Blockchain Traceability Capability	Pearson Correlation	1	.827**	.747**	.766**	.806**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	259	259	259	259	259
Blockchain Data Immutability	Pearson Correlation	.827**	1	.779**	.847**	.866**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	259	259	259	259	259
Smart Contract Automation	Pearson Correlation	.747**	.779**	1	.818**	.800**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	259	259	259	259	259
Stakeholder Data Accessibility	Pearson Correlation	.766**	.847**	.818**	1	.855**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	259	259	259	259	259
Supply Chain Transparency	Pearson Correlation	.806**	.866**	.800**	.855**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	259	259	259	259	259

Correlation analysis is a statistical methodology to measure the strength of relationships between two variables and the direction of these relationships. The analysis was performed using Pearson correlation coefficients in the present study that helped to identify the linear association between the five core constructs of blockchain and supply chains in the fashion industry: Blockchain Traceability Capability (BTC), Blockchain Data Immutability (BDI), Smart Contract Automation (SCA), Stakeholder Data Accessibility (SDA), and Supply Chain Transparency (SCT). All correlations were significant at the 0.01 level(two-tailed), meaning the associations were powerful. All variables have positive significant correlations with each other, and as shown in the findings, the positive relationship is substantial.

BTC had the highest correlation with BDI ($r = 0.827$, $p < .001$), thus supporting the literature that considers tamper-proofness as the essential characteristic that assists in providing traceability of supply chains across the globe (Saberi et al., 2019). By ensuring that recorded information on products (including their material origin or labor standards properties), immutable records make traceability data more reliable (Gariba et al., 2024). There was also a close relationship between BTC and SCT ($r = 0.806$, $p < .001$), to the argument that end-to-end visibility is built on the foundation of traceability. Traceable records that support transparency, as defined, that is, seeing an event or condition on the supply chain, include: the sourcing, the production line, and the delivery line (Ahmed and McCarthy, 2021). Strong relationships with SDA ($r = 0.766$) and SCA ($r = 0.747$) further suggest that sharing and automated data checking increases traceability.

BDI exhibited the most stable relationship with SCT ($r = 0.866$, $p < .001$), reaffirming the perspective that immutability is the key element contributing to supply chain information trust. Stakes can result in sustainability, compliance, and sourcing claims when the data can be reverse updated. Politou et al. (2019) confirm that inalterability establishes faith among the stakeholders and is a significant component of ethical disclosures. BDI also showed a high positive relationship with SDA ($r = 0.847$) and SCA ($r = 0.779$), meaning that immutable data enhances accessibility and automation. The immutable ledgers also allow stakeholders to retrieve valid data in real-time, automating the contract process (Thilakavathy et al., 2023). The good correlations between BDI and BTC, as shown above, indicate that immutability supports the capability network rather than an isolated system.

The relationship between SCA and SDA was especially sharp (r = 0.818, p < .001), indicating that automation works better when stakeholders have smooth access to information. The use of smart contracts assumes the participation of various parties along the supply chain in providing inputs (Hasan et al., 2019). When data becomes not easily accessible and verifiable, automation is undermined. This symbolizes the mutual dependence of blockchain systems. There was also a significant connection between SCA and SCT (r = 0.800), which confirms the argument of how automated execution of compliance and sustainability terms can enhance real-time visibility. Smart contracts, in particular, can automatically unlock the payment after receiving the shipment or initiate ESG reports according to prescribed targeted sustainability indicators (Ullah and Chowdhury, 2025). It is also highly associated with BDI (r = 0.779) and BTC (r = 0.747), which shows that automation depends on data accuracy and traceability of data.

SDA portrayed one of the strongest correlations with SCT (r = 0.855, p < .001) and that better data availability to the stakeholders is the key to realizing transparency. With conventional supply networks, data systems are in silos where collaboration and accountability are inhibited. A blockchain decentralized system enables the actors, suppliers, regulators, etc. to access and validate the data (Vadgama et al., 2019). SDA (r = 0.847) and BDI (r = 0.847) correlations indicate that data records immutable and decentralized to the database improve accessibility, which limits the risk of proving data correct by intermediaries. The interrelations between SDA and SCA (r = 0.818) and BTC (r = 0.766) further indicate that data sharing is a premise of achieving the full potential of blockchains. Data availability in an efficient and standardized way significantly allows the smart contract to be effective and verify evidence like wages, pay, and materials source.

The SCT has a high correlation with all other constructs, with the highest correlation with BDI (r=0.866), SDA (r = 0.855), BTC (r = 0.806), and SCA (r = 0.800).

4.2.5 Regression Analysis

Model Summary

Table 16: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.906[a]	.821	.819	.3110

The regression model summary suggests a strong predictive correlation between the independent variables, i.e., Blockchain Traceability Capability, Data Immutability, Smart Contract Automation, and Stakeholder Data Accessibility and the dependent variable, Supply Chain Transparency. The R value of 0.906 indicates a robust positive relationship between the observed and the predicted supply chain transparency, implying that the model should be able to represent the data appropriately. An R Square (R^2) of 0.821 suggests that the blockchain-related variables contained in the model explain around 82.1 per cent of the variance in supply chain transparency, which supports the power of items in explaining that variance. The fact that the number of predictors and the sample size were included with the Adjusted R Square value of 0.819 further substantiates the efficacy and robustness of the model to the constraints of overfitting. The standard error of the estimate (0.3110) signifies that the model makes estimates of supply chain transparency that, on average, are bound by a relatively narrow margin.

Anova

Table 17: ANOVA table

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	113.026	4	28.256	292.141	.000[b]
	Residual	24.567	254	.097		
	Total	137.593	258			

ANOVA output evaluates whether the model as a whole can Explain a significant proportions of variance and determines whether variables (blockchain traceability capability (BTC), data immutability (BDI), intelligent contract automation (SCA), and a stakeholder data accessibility (SDA)) used by a regression model are significantly correlated with the variable, which it is supposed to explain (Supply Chain Transparency (SCT)). The model F-statistic is 292.141 with a p-value of .000, significantly below the traditional 0.05 limit. It means the model is statistically significant, proving the existence of at least one independent variable that plays a vital role in the prediction of supply chain transparency. As a result, the variation in transparency observed in the sample of participants cannot be attributed to chance alone. It can be significantly explained by the set of blockchain capabilities incorporated into the model.

The Sum of Squares for Regression (113.026) and the Total Sum of Squares (137.593) show that a very considerable percentage of the variation of SCT is explained by the model, equivalent to an R 2 value of 0.821, as it has been indicated above. The Mean Square Regression (28.256) is significantly higher than the value of the Mean Square Residual (0.097), which shows again that the variability that the model explains is larger than the unexplained (error) variability. Such results confirm literature stating that blockchain is a revolutionary technology that can provide transparency through immutable records, real-time traceability, and automated compliance (Ahmed and McCarthy, 2021; Saberi et al., 2019). The valid ANOVA outcome as statistically significant confirms the overall efficacy of blockchain potential in projecting the cost of transparency in the fashion supply chain.

Coefficients

Table 18: Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	.161	.114		1.411	.159
	Blockchain Traceability Capability	.167	.049	.171	3.445	.001
	Blockchain Data Immutability	.346	.059	.348	5.896	.000
	Smart Contract Automation	.152	.049	.151	3.076	.002
	Stakeholder Data Accessibility	.297	.056	.305	5.354	.000

The regression coefficients table is one of the most essential tools for determining the singular input of each independent predictor in predicting Supply Chain Transparency (SCT) based on blockchain capabilities. The table has unstandardized and standardized data, which makes it easy to interpret the size of a direct effect (B values) and relative importance (Beta values) of all the predictor variables.

The intercept or constant term represents the forecasted value of SCT with every variable representing blockchain at zero. It has a p-value of 0.159, which means it is not statistically significant; this is not unusual in the field of social inquiry, and thus the null hypothesis stating that the constant can meaningfully affect the model on its own cannot be rejected. The finding of the BTC and SCT correlation could be considered statistically significant and positive, where the p-value is <0.0005. The unstandardized coefficient of 0.167 shows that an increase of one unit in perceived capability of traceability corresponds to an increase of 0.167 in SCT with other predictors kept constant. The standardized Beta coefficient of 0.171 reflects a modest contribution compared to the different variables. This is consistent with Saberi et al. (2019), which states that tracking granular material through traceability increases accountability and instils supply chain transparency.

BDI comes out as the most powerful forecaster. Its coefficient 0.346 demonstrates a high positive relationship between blockchain immutability and perceived transparency. The respective standardized Beta of 0.348 confirms that predictor BDI has the most significant standardized impact of all predictors, meaning that enhancements of blockchain tamper-resistance are most closely related to perceived transparency. Politou et al. (2019) note that the immutable recordkeeping reduces the risks of post-hoc data manipulation and, thus, hardens audit trails. Such immutability increases ESG assurance and regulatory compliance in the fashion industry, characterized by opaque sourcing (Ahmed and McCarthy, 2021).

SCA describes a positive and statistically significant outcome on SCT with the B value of 0.152; likewise, the Beta of 0.151. Intelligent contract automation, although ranked lower than BTC or BDI, still has a positive effect on SCT, which is why Hasan et al. (2019) explain that smart contracts are used as tools that ensure rule-based and automated rules verification, e.g. ESG checks or confirmation of delivery, reducing the error rate caused by employees and increasing real-time data reliability. Such automation's transparent, accountable workflows in highly distributed networks are critical to fashion logistics and sourcing.

4.3 Qualitative Analysis

4.3.1. Introduction to Qualitative Data Analysis

Thematic analysis was utilized as a method of qualitative data analysis to discover and code important themes in the interview responses. These interviews gave important information regarding the implementation of the blockchain in the fashion supply chain and how it could be used to increase transparency, traceability, and sustainability. Using the themes analysis, data was orderly reviewed so that the research could draw recurrent patterns, ideas and information that fall supportive to the research questions.

4.3.2. Data Familiarization and Initial Coding

4.3.2.1. Data Familiarization

The answers in the interviews were analyzed with the same level of rigor to understand the major issues, opportunities and perceptions about adopting blockchain in fashion supply chain in detail. Data familiarization this technique just entailed reading over all the responses severally. This move has given the chance to recognize common cases and lessons coordinated to transparency, traceability, data precision, sustainability, and moral issues.

This was meant to receive a comprehensive insight into the perceptions of the respondents about how blockchain technology will leverage the supply chain efficiencies in the fashion industry, meet sustainable development goals (SDGs) and benefit Environmental, Social, and Governance (ESG) objectives. It was also important to factor in the challenges to blockchain adoption noted by participants, including the implementation costs of the technology, as well as the technological infrastructure that would be required to increase scale of blockchain offerings.
Individual treatment of each response was applied with the aim of determining certain details that would concur with the interests of the research hence making it possible to create an extensive thematic map. In the process, the research identified emerging trends that provided information on opportunities and challenges experienced by organizations in implementing blockchain to supply chain transparency.

4.3.2.2. Initial Coding

In the first phase of coding, key expressions in the answers were noted, which include the lack of traceability and the effect it has on transparency. Coding was done to note recurring themes like Data Accuracy, Blockchain Adoption, Ethical Sourcing and Sustainability Standards as the codes for each answer.

Table 19: Initial Coding

Response No.	Interview Response (Exact Text)	Assigned Code(s)	Explanation
1	"Blockchain plays a significant role in improving supply chain transparency by providing a secure, immutable, and decentralized platform for recording transactions."	Blockchain for transparency	Blockchain ensures secure, immutable, and decentralized records, enhancing supply chain transparency.
2	"Implementing blockchain within our current operations may face several challenges. First, there is a lack of technical expertise and understanding among staff."	Lack of technical expertise	Technical expertise is identified as a key challenge in implementing blockchain.
3	"The biggest visibility gaps in our supply chain today include limited real-time tracking of raw materials, insufficient data sharing among suppliers and partners."	Visibility gaps in tracking	Identifies visibility gaps such as real-time tracking and insufficient data sharing in the supply chain.
4	"Data accuracy is critical for making effective day-to-day supply chain decisions. Accurate data ensures that inventory levels, delivery schedules, and production planning are based on reliable information."	Data accuracy for decision-making	Highlights data accuracy as essential for inventory management, delivery schedules, and production planning.
5	"Traceability is essential for meeting our company's sustainability goals. It allows us to track the origin and journey of raw materials, ensuring they come from ethical and environmentally responsible sources."	Traceability for sustainability	Emphasizes traceability for ensuring ethical and environmentally responsible sourcing to meet sustainability goals.
6	"Our sourcing practices are guided by internationally recognized sustainability standards and frameworks such as the Global Reporting Initiative (GRI), the Sustainable Apparel Coalition's Higg Index, and the United Nations Sustainable Development Goals (SDGs)."	Sustainability frameworks	Lists GRI, Higg Index, and SDGs as the main sustainability frameworks guiding sourcing practices.
7	"Digital innovation has transformed supply chain dynamics in the fashion sector by enhancing speed, transparency, and flexibility."	Digital innovation for speed and transparency	The role of digital innovation in enhancing speed, transparency, and flexibility in supply chains.

8	"Blockchain technology has the potential to significantly enhance supply chain transparency by creating a secure, immutable, and transparent record of transactions and product movements."	Blockchain for transparency	Blockchain is identified as enhancing transparency through immutable and transparent records.
9	"Implementing blockchain in current operations faces challenges like high initial costs, scalability issues, security concerns, regulatory uncertainty, and the need for interoperability with existing systems."	Blockchain implementation challenges	Challenges include costs, scalability, security, regulatory uncertainty, and interoperability.
10	"The biggest visibility gaps in supply chains today include a lack of real-time data, disparate systems, poor communication, and limited visibility into last-mile delivery."	Visibility gaps in data and communication	Visibility gaps are noted in real-time data, disparate systems, and communication in supply chains.
11	"Data accuracy is crucial for effective supply chain decision-making. Accurate data enables better planning, reduces errors, and improves overall efficiency."	Data accuracy for planning	Data accuracy is tied to better planning, reducing errors, and improving efficiency in decision-making.
12	"Traceability is crucial for meeting sustainability goals because it provides transparency and accountability throughout the supply chain, enabling companies to identify and address environmental and social impacts."	Traceability for sustainability goals	Traceability is vital for ensuring transparency and accountability to meet sustainability goals.
13	"Several standards and frameworks guide sustainable sourcing practices. Key among them are ISO 20400 for sustainable procurement, which offers guidelines on integrating sustainability into purchasing decisions."	Sustainability frameworks for sourcing	ISO 20400 and other frameworks guide sustainable sourcing in procurement.
14	"Digital innovation has fundamentally reshaped supply chain dynamics in the fashion sector, leading to increased efficiency, transparency, and sustainability."	Digital innovation for efficiency	Digital innovation has reshaped supply chains by enhancing efficiency, transparency, and sustainability.
15	"Blockchain technology is revolutionizing supply chain transparency by introducing immutable traceability, real-time visibility, and decentralized trust across global networks."	Blockchain for revolutionizing transparency	Blockchain is seen as revolutionizing transparency with immutable traceability, real-time visibility, and decentralized trust.

16	"Here are the most critical visibility gaps commonly found in supply chains: Tier 2 supplier Blindspots, Real-Time Inventory Discrepancies, Transportation Black Holes, and Production Status Opacity."	Visibility gaps across suppliers and transportation	Visibility gaps include Tier 2 supplier blind spots, inventory discrepancies, and transportation black holes.
17	"Data accuracy directly influences supply chain efficiency, cost control, and customer satisfaction."	Data accuracy influencing efficiency	Data accuracy is critical for efficiency, cost control, and customer satisfaction in supply chain operations.
18	"Traceability is no longer optional—it's the backbone of credible sustainability strategies. Compliance & Risk Mitigation, Ethical Sourcing Verification, Circular Economy Enablement, Carbon Footprint Precision."	Traceability as the backbone of sustainability	Traceability is essential for compliance, risk mitigation, ethical sourcing, and carbon footprint tracking.
19	"Several sustainability standards and frameworks guide sourcing practices. Key among them are Environmental Standards, Social Compliance, Climate Action, and Circular Economy."	Sustainability standards and frameworks	Environmental, social, and climate standards are listed as key frameworks for guiding sourcing practices.
20	"Digital innovation has dramatically transformed our supply chain, improving traceability and sustainability."	Digital innovation for traceability	Digital innovation is credited for improving traceability and sustainability in supply chain operations.

4.3.3. Development of Themes

Table 20: Table of Major Themes

Theme	Sub-Themes	Key Findings	Example from Data
Blockchain for Transparency	- Blockchain for trust and accountability	Blockchain is seen as essential for improving supply chain transparency by ensuring secure, immutable, and decentralized tracking of transactions and product movements.	"Blockchain plays a significant role in improving supply chain transparency by providing a secure, immutable, and decentralized platform for recording transactions."

Barriers to Blockchain Adoption	- High setup costs	Challenges in blockchain adoption include high initial costs, lack of technical expertise, and resistance to change.	"Implementing blockchain within our current operations may face several challenges. First, there is a lack of technical expertise and understanding among staff."
Data Accuracy and Sustainability	- Accuracy in forecasting and inventory management	Accurate data is critical for operational efficiency, sustainability reporting, and maintaining overall transparency in the supply chain.	"Data accuracy is critical for making effective day-to-day supply chain decisions. Accurate data ensures that inventory levels, delivery schedules, and production planning are based on reliable information."
Ethical Concerns and Visibility Gaps	- Supply chain opacity	Key ethical concerns include forced labor, unsafe working conditions, and environmental degradation. Visibility gaps affect Tier 2 and Tier 3 suppliers.	"The biggest visibility gaps in our supply chain today include limited real-time tracking of raw materials, insufficient data sharing among suppliers and partners."
Digital Innovation in Supply Chain	- AI, IoT, and blockchain integration	Digital innovation through AI, IoT, and blockchain has significantly transformed supply chain dynamics, improving efficiency and responsiveness.	"Digital innovation has transformed supply chain dynamics in the fashion sector by enhancing speed, transparency, and flexibility."

The table above offers an organized overview of the key themes explored in the present study in accordance with the qualitative interview analysis. It summarizes responses of similar parameters and gives an outline of the major findings regarding specific themes. The determined themes are Blockchain for Transparency, Barriers to Blockchain Adoption, Data Accuracy and Sustainability, Ethical Concerns and Visibility Gaps, and Digital Innovation in Supply Chain. The themes are also subdivided into sub themes that point at areas of focus within the main theme. As an example, Blockchain for Transparency has the sub-theme that focuses on blockchain in establishing trust and accountability within the supply chain. Direct quotes of the interview participants are being used to support every theme, and this gives real life illustrations to the main findings. The quotes help in validating the findings and base them on the real-life experiences as well as perceptions of the participants. The table allows connecting the major themes with the sub-themes and the examples of data to reveal a vivid, laconic picture of the research findings offering clear structure to be used in analyzing and discussing the topic in the thesis. This practice is not only transparent and credible but also allows pointing out the most important issues about blockchain adoption and its effects on the transparency of a supply chain, its sustainability, and ethical peculiarities.

4.3.4. In-depth Analysis of Themes

4.3.4.1. Blockchain for Transparency

Multiple participants expressed that blockchain can profoundly enhance transparency in supply chains. One participant explained:

"Blockchain plays a significant role in improving supply chain transparency by providing a secure, immutable, and decentralized platform for recording transactions."

In addition, another participant shared:

"Blockchain significantly enhances supply chain transparency by creating a secure, decentralized, and immutable record of transactions, enabling real-time tracking, improved traceability, and reduced fraud."

A third participant echoed similar sentiments, stating:

"Blockchain enhances transparency by enabling secure, shared, real-time data, ensuring authenticity and compliance."

Similarly, the responses that guard the benefits of blockchain consistently give the importance of a secure, immutable and transparent medium of recording the transactions and in that way the real time supply chain visibility can be attained in an end-to-end manner. The most important part of blockchain is the decentralization of the ledger, which ensures that no one can change the records of the transaction, making it more reliable and responsible. This in terms of supply chains implies that all the stakeholders involved such as manufacturers, suppliers, retailers and consumers can share the same data and confirm the authenticity of shared information. This makes the risk of fraud and falsity much lower, especially relating to origin and quality of products which are especially pertinent in industries of fashion where ethics of supply and sustainability are a factor.

Moreover, participants also said that blockchain has the potential to advance more ethical sourcing because it allows stakeholders to establish the source of raw material in a supply chain which would otherwise be opaque in more traditional supply chains. As one of the participants has observed, blockchain might be used to verify sustainable production processes or fair work of products. The significance of this relationship between blockchain and ethical sourcing is that the companies can show the origins of their products, the conditions of the labor and impacts on environment in the form of public disclosure and this will enable the customers to obtain valid resources on the product they buy.

These answers are in line with the literature available, which proves the fact that blockchain could enhance supply chain transparency by providing the ability to track the chain in real-time and audit all transactions made. According to Casino et al. (2019), blockchain has the potential to minimize fraud, enhance traceability capacity, and facilitate ethical sourcing, especially through maintaining the integrity of the data of products throughout the product lifecycle, origin to consumer.

The use of blockchain in the visibility of the supply chains is a topic that is being debated in the current research. As an example, Ahmed and MacCarthy (2021) highlight the effectiveness of blockchain technology in tracing the products throughout the whole supply chain and, therefore, its usefulness to demonstrate the authenticity of the products and ensure ethical sourcing. This traceability feature is of great value to such industries as fashion where disclosure of such materials and means of production has become more and more demanded among people who care much about their sustainability and eco-friendly approach to production.

In turn, the study by Kshetri (2018) examines how blockchain will also be able to make sure that data within the supply chains is secure and, at the same time, transparent. Blockchain can be used to unlock confidence in business and consumers by offering a tamper-proof ledger to ascertain the quality and source of products. It is also relevant to the wider understanding of the corporate responsibility and sustainability in inter-global chains of supplies where due to the absence of visibility and confidence it may proceed into ethical abuse and environmental degradations. These issues can be solved through blockchain, which provides greater visibility and, thus, this finding corresponds with the statements provided by the respondents in this study.

Second, Bai and Sarkis (2020) state that sustainable supply chain management might become a game-changer through blockchain. Their study agrees with the findings of the research conducted in this paper implying that blockchain has the capacity to improve transparency to both consumers and regulatory organs where such organs can easily confirm that companies are complying with the environmental and social requirements. Incorporated within its nature, blockchain allows tracking the whole lifecycle a product goes through, which makes companies more likely to divulge their environmental footprint and sustainability indices, essential to establishing consumer confidence in an environmentally mindful market.

The results of both the answers and the literature propel to the same point that blockchain is ready to increase transparency and trust within supply chains especially in an industry with complex, global networks such as fashion. The possibility to trace products and confirm authenticity throughout the raw materials stages until the delivery are primary elements of the realization of ethical sourcing and sustainability objectives. The imminence and real-time traceability functions of blockchain create transparency, which offers enhanced decision-making, responsibility, and consumer trust. Nonetheless, according to the participants of the study, technical obstacles, financial barriers, and interoperability concerns will be central to realize the full potential of blockchain to transparency in supply chains.

4.3.4.2. Barriers to Blockchain Adoption

Despite their enthusiasm for blockchain technology, participants identified several significant barriers to adoption within their organizations. A recurring concern was the high initial cost and technical challenges associated with implementing blockchain. One participant shared:

“Implementing blockchain within our current operations may face several challenges. First, there is a lack of technical expertise and understanding among staff.”

Another participant emphasized the difficulty in integrating blockchain with existing systems, stating:

“The biggest challenge is ensuring compatibility between blockchain and our legacy systems, which requires considerable investment in technology and training.”

Additionally, concerns regarding financial investment were raised, with one participant noting:

“The upfront costs and ongoing maintenance required for blockchain technology are significant barriers, especially given the uncertain returns on investment in the short term.”

These answers allude to two key obstacles; technical knowledge and economic restrictions. Implementation of blockchain may necessitate specialization and training that can prove to be an obstacle in implementing blockchain to organizations with less working experience on new technologies. Implementation may be delayed by the absence of technical capacity of staff as well as integration challenges with existing systems. Besides, blockchain is expensive to adopt due to the substantial start-up cost such as infrastructural investment, integration, and training; hence, companies are unable to justify such investments especially on products where the payoff is long-term and not immediate. This is in line with the study conducted by Casino et al. (2019), which pays attention to the fact that large initial expenses, as well as the absence of technical skills, are some of the main problems that hinder the adoption of blockchain in supply chain management.

The resistance to change in the organization was also identified by the participants, where some stakeholders may not be willing to use blockchain since they are not used to the technology or fear interfering with the current workflows. This is coupled with the technological uncertainty caused by this fear of change, which poses a significant challenge towards implementing blockchain, since any organization might be reluctant to migrate towards the new system of processes.

The identified barriers in the responses agree with some of the major studies on adopting blockchain. The authors emphasize that financial constraints and thematic literacy concerning blockchain are major barriers, at least in the case of the small and medium-sized enterprises (SMEs) (Ahmed and MacCarthy, 2021). SMEs also do not have the considerable amount of finance needed to implement blockchain and also find it challenging to attain the technical expertise needed to make effective use of the technology. This is because in the responses provided, the participants cited the absence of internal expertise and the necessity to have specialized pre-existing knowledge as main issues.

Another reason why blockchain is not being widely adopted by companies is mentioned by Kshetri (2018), and that is interoperability concern between the blockchain platform and the legacy systems in the company. Although joining blockchain with the current systems entails technical skills as well as a notable amount of investment in upgrading the existing systems, this may act as a discouraging factor to blockchain adoption by organizations. This concern can be seen through one of the responses on integration challenges, as the legacy systems frequently do not prove flexible enough, in order to integrate blockchain effortlessly.

Besides, Gallego (2025) address the regulatory uncertainty and resistance to changes as the other obstacles to blockchain implementation. They make the claim that the disruptive potential of blockchain in the realm of traditional industries and especially in the sphere of such established area as fashion is usually met with cultural opposition. The sale and application of new technologies might not be well received by the employees and the stakeholders in case it threatens the current process or the job roles. In this respect, companies should address technical and cultural obstacles to effective adoption of blockchain in supply chains.

Lastly, Ahmed and MacCarthy (2021) point out that the implementation of blockchain is specifically problematic with the organization located in a developing region or one that is not used to technologically sophisticated digital technologies. Inability to deploy blockchain may occur in the absence of proper infrastructure and technological preparedness of a given sector; this may stall the implementation of blockchain in any given sector, especially one that depends on old and manual systems. A response analysis has shown that even though blockchain has important implications in terms of supply chain transparency, its adoption obstacle is quite high. These barriers are mainly: financial investment, technical expertise gaps, integration in the background systems and organizational resistance to change. The present results echo other literature that identifies the same issues experienced by firms in the processes of adopting new emerging technologies. These barriers can only be surmounted by making an effort to invest on technical training, generate compatible integration policies, and execute management of organizational change. In the future with continued development of blockchain, these barriers will have to be addressed to maximize the potential of blockchain in supply chain management.

4.3.4.3. Data Accuracy and Sustainability

Participants consistently emphasized that data accuracy is a fundamental factor for both effective supply chain management and the achievement of sustainability goals. One participant shared:

"Data accuracy is critical for making effective day-to-day supply chain decisions. Accurate data ensures that inventory levels, delivery schedules, and production planning are based on reliable information."

Another participant echoed similar thoughts:

"Accurate data enables better planning, reduces errors, and improves overall efficiency. Conversely, inaccurate data can lead to costly mistakes, inefficiencies, and decreased customer satisfaction."

The above responses demonstrate that the accuracy of data has a direct relationship to several elements of supply chain operations, such as inventory management, forecasting demand, as well as fulfilment. The interrelation of the correct data and sustainability is of unique importance. As an example, when there is an environment of sustainable activities like the source of materials used, carbon footprint monitoring, etc., credible data helps to make sure that the initiatives are carried out, recorded and followed up appropriately.

Inefficiency, on the other hand, arising due to wrong data may be disastrous in the form of stockouts, wastage, and overproduction and so on, which also subverts sustainability initiatives. As an example, when companies work on wrong data of the goods available on stock, then there is a possibility of overstocking a resource in the warehouse, the resources get to the expiry date leading to an excess emission of the inventory due to the globally harmful carbon emission. Additionally, false information about the demand forecasting can result in either redundancy or loss of potential, and both cases are harmful to the sustainability objectives as they bring in efficiencies. This agrees with Marques et al. (2025) who stipulate that essential data is critical in making decisions supporting sustainable procurement practices.

In addition, respondents identified the fact that decisions that are based on data would be necessary to make supply chains both effective and sustainable. Correct data assist companies to make quality decisions regarding allocation of resources by making sure that the production processes involve minimal wastage and energy use. This will help companies to increase their reach to the environmental targets, minimize carbon emissions and also keep an eye on their supply chain effect.

Several studies have been carried out on the relationship between the accuracy of data and sustainability. According to Wang and Walker (2023), data-driven decisions make operations in a company more efficient allowing to optimize the input and minimize the number of consumed resources thus saving resources thus facilitating greener supply chains. Their results indicate that in circumstances where companies possess quality information, they are capable of utilizing resources efficiently, waste generation minimization, and an attainment of the sustainability goals which is quite similar to the reflections of participants.

As well, Gupta et al. (2024) note that data precision is a key component of traceability and accountability, which should be present in ethical sourcing and sustainability reporting. In an industry like fashion where the source of products, working conditions of all laborers, and environment are major factors to be disclosed, the accuracy of data is very important as it enables firms to confirm their claims of being sustainable and related to ethical practices. Lack of proper information can make a company find it difficult to offer convincing information about their sustainability efforts hence difficult to earn consumer and regulatory trust.

What is more, Treiblmaier (2019) emphasizes that supply chain visibility that is based on quality data can enhance the decision-making and eliminate inefficiencies. In their study, it indicates that in the absence of accurate and valid information, supply chains are more likely to be disruptive, delayed, and wasteful, hence, jeopardizing economic as well as environmental sustainability. The problem is that the efficiency of sustainability initiatives is conditioned by the existence of an efficient system of data, which can be tracked on a regular basis and in real time, as participants pointed out.

Finally, Marques et al. (2025) also claims that by relying on data analytics, one can enhance supply chain performance immensely, at least when discussing reducing waste and managing inventory and planning production. They emphasize that sustainable operations also demand that businesses do not only gather data but also use it to pursue ongoing process amelioration and sustainability performance.

Issues relating to accuracy of data in the attainment of sustainability in supply chain are critical. The analysis indicates that inaccurate information may cause inefficiencies like overproducing goods and waste as well as poor usage of resources, which are counterproductive towards the goals of sustainability. High quality data, rather, allows predictability, ethical supply/selling, and tracing, and makes the sustainability claims verifiable and makes the businesses conform to the environmental regulations. These results corroborate with the current literature reflecting the role of data integrity as a focus in sustainable supply chain management. Companies have to be serious in achieving their sustainability goals, one of which is to see that they achieve data accuracy in their supply chain operations.

4.3.4.4. Ethical Concerns and Visibility Gaps

A major theme that emerged from the responses was the issue of ethical concerns and visibility gaps within the supply chain, particularly related to Tier 2 and Tier 3 suppliers. One participant stated:

"The biggest visibility gaps in our supply chain today include limited real-time tracking of raw materials, insufficient data sharing among suppliers and partners, and lack of end-to-end transparency from production to delivery."

Another participant emphasized similar challenges, mentioning:

"We have limited visibility into supplier networks, especially sub-tier suppliers, and a lack of real-time data on inventory levels and shipment locations. Poor communication and data sharing between supply chain partners create significant blind spots."

This claim highlights the importance of the supply chain with critical visibility holes, particularly, in terms of tracking source and supply of raw materials and ethical responsibility. The Tier 2 and Tier 3 suppliers present a serious problem as far as the validation of ethical labor conditions and environmental regulations are concerned as they can be found in the areas with minimal regulations or the lack thereof, which creates a serious problem regarding the verification of the ethical labor practice and environmental standards. These areas in the supply chain cannot be tracked easily hence companies cannot trace their compliance to sustainability such as social and environmental effects of the operations.

The issue of the lack of visibility of these levels of supply is also a constant one with firms being better placed to control and observe their immediate suppliers (Tiers 1) but also in a position of not being capable of tracking higher. This poses a certain risk of forced labor, child labor as well as environmental degradation which companies are not even aware of supporting because of no clarity in these dark corners of the supply chain. According to the response, the absence of data sharing and little monitoring of the materials increase these gaps and makes it more difficult to achieve their ethical sourcing objectives.

Blockchain may be the central answer to these sight problems. Blockchain will enable a clear and unchangeable register that traces the movement of products and raw materials between source and final consumer, thus improving the degree of visibility and real-time monitoring of the supply chain. This might in turn aid in the realization of risks as regards to the issue of force labor, environmental offences, and other issues revolving around sustainability. Such a solution aligns with Daniel et al. (2019) who note that the characteristics of blockchain to promote the visibility and offer traceability are likely to contribute to eliminating the ethical risks and transparency shortages existing within supply chains and the harder locations to monitor.

The concern of the supply chain secretiveness, especially in the lower rungs of the supply chain, has extensively found its way in the literature. According to Narula (2019), one of the greatest threats to sustainability and ethical sourcing is the fact that the visibility of supply beyond Tier 1 is not visible. According to them, without effective data sharing and tracking systems, companies cannot be sure in responsibilities of sourcing their product and absence of contribution into unsustainable practices and crimes against human rights. This is in line with the responses by the participants as they mentioned that Tier 2 and Tier 3 vendors are usually most challenging to observe and real-time information is the most important aspect of eliminating the gap in visibility.

In the same line of thinking, Kshetri (2018) explains that an end-to-end traceability feature provided by blockchain can solve the problem as companies will have the opportunity to trace products and materials origin to the final destination. Traceability of this kind makes sure that all components of the supply chain act ethically and environmentally sound. Blockchain is also used to establish an open registry that will show the distribution of products to each point of the supply chain to allow companies to realize possible risks in the supply chain and manage them proactively to make sure that the sustainability requirements are achieved.

Moreover, Pesqueira et al. (2025) also state that blockchain could fill visibility gaps and provide real-time monitoring and traceability of data that can promote better governance of the supply chain through its auditable data. These results help to support the answers given by the participants, who were concerned about the absence of real-time tracking and sharing of data in their supply chains. Utilizing the benefits of blockchain, the companies will have better control over their supply chain and minimize the risks related to ethical sourcing and sustainability of the environment. Moreover, according to Treiblmaier (2019), a supply chain is not usually observed, which in turn causes certain inefficiencies and ethical dilemmas that can be fixed with blockchain due to providing reliable and immutable history of transactions and the product. It is especially influential in such an industry as fashion, where sustainability and ethical sourcing arguably take central stage among the consumers and their regulators.

The response analysis indicates the existence of large visibility gaps in the supply chain, especially to Tier 2 and Tier 3 suppliers. These lesser tiers do not observe real-time monitoring of the process, limited data exchange, and insufficient visibility, necessitating organizations in making sure their source is ethical and supporting their sustainability targets. Blockchain technology can also be a solution to these difficulties such as its end-to-end traceability, their real-time data sharing, secure records would guarantee their compliance with the ethical requirements and environmentally friendly way of work. This is consistent with the current literature that has highlighted the importance of blockchain in improving transparency, accountability as well as traceability in supply chain, whereby organizations will be in a better position to inspect their supply chain in an overall manner which would be quite ethical.

4.3.4.5. Digital Innovation in Supply Chain

Participants in the study emphasized the importance of digital innovation in enhancing supply chain dynamics, particularly within the fashion industry. One participant remarked:

"Digital innovation has transformed supply chain dynamics in the fashion sector by enhancing speed, transparency, and flexibility. Technologies like blockchain, IoT, and AI enable real-time tracking of products, improved demand forecasting, and better inventory management."

Another participant added:

"Technologies like blockchain, AI, and IoT are driving real-time tracking, better demand forecasting, and efficient inventory management. These innovations allow us to optimize our supply chain performance and reduce operational inefficiencies."

The responses can identify the great potential value of modern digital technologies: AI, IoT, blockchain, are able to modernize operations of supply chains. Namely, AI improves the demand forecasting process, enabling companies to better forecast the consumer demand and schedule their production. In contrast, blockchain and IoT promote the following in real-time since it is possible to track goods through the entire supply chain: visibility and transparency. Such traceability is crucial in minimizing wastage and fraud as well as in free flow of products through supply chain, starting at the raw materials level and ending up at the finished product.

Moreover, the convergence of the technologies allows connection between the stakeholders, which is why sharing data in real-time and communicating with each other is possible. The partnership is also essential in meeting the sustainability objectives because there is improved tracking of the use of resources, the detection of wastage and the most efficient production methods. Digital technologies also have the potential to make companies more environmentally friendly by allowing them to make speedier, smarter decisions, thereby lowering their carbon footprint, energy requirements and wastes, making their supply chains more sustainable in nature. These results correlate with the findings of Salomone (2023), who point out that innovation in digitalization is a significant contributor to operational efficiency and sustainability through the ability of companies to optimize the response to demand swings and waste and resource optimization.

Digitizing supply chains has received major attention in the recent literature. Fahdil et al. (2024) believe that blockchain, IoT, and AI are crucial to the resilience of the supply chain, and sustainability. These technologies enable corporations to do more than increase efficiency but also monitor and report more easily environmental and social effects. Blockchain, as another example, offers non-editable records to trace environmental impact of the product at its entire lifecycle and IoT devices may trace energy consumption, materials used, and waste in real time. Such integration allows businesses to make information-based decisions based on sustainability objectives and enhancing their environmental performance.

Likewise, Kshetri (2018) points out that sustainability is promoted with the help of digital innovation emerging in the form of blockchain, AI, and IoT, contributing to the improvement of the supply chain visibility. All stakeholders being provided with the same real-time data will help the companies to observe practices in the supply chains better; thus, the issues impounded on environmental deformations, human right abuse and unethical sourcing can also be corrected. These technologies lead to more ethical sourcing and ensure that the sustainability standards are met throughout the chain of supply.

Furthermore, Ahmed and MacCarthy (2021) underline the importance of IoT in sustainability more as the entities could use it to maximize their consumption of resources, monitor the waste, and minimize inefficiencies. Temperature, relative humidity, and the use of energy can be monitored by IoT sensors that are installed along the supply chain, and materials and products will be delivered and stored in the most energy-efficient manner. This omnipresent surveillance minimizes the ecological cost of supply chain activities, which helps the business go greener.

The collaboration of AI, IoT, and blockchain in the area of supply chains is also essential to increase efficiency, enhance real-time visibility, and bring data-driven decision-making. As the responses show, such technologies are not only streamlining the operations of the supply chains, but they are also making them sustainable as associated with minimization of waste, energy wastage and carbon emission. This discovery corroborates with the existing literature in which other scholars such as Fahdil et al. (2024); Kshetri (2018) stress that digital innovation is vital in developing more resilient, transparent and sustainable supply chains. Faced with adopting these technologies, businesses will be in a better position to cope successfully with consumer demand, lower their operating costs and meet their sustainability objectives.

4.4 Chapter Summary

This chapter combines quantitative and qualitative evidence to understand how far blockchain technology can lead to supply chain transparency in the fashion industry. The quantitative information covering 259 professionals within the industry indicates extensive awareness of the benefits of using blockchain but reports low adoption levels overall. Descriptive analyzes indicate that the traceability, immutability, smart-contract functionality, and the availability of stakeholder data are mainly viewed positively. Follow-up regression and correlation analysis reveal that immutability of data and its accessibility by stakeholders are the best predictors of transparency in the supply chain, which proves their essential role in accountability and ESG alignment. The qualitative component provides contextual depth. Sourcing managers, compliance officers, and operations members' interviews explain the practical barriers, such as the unacceptable cost of implementation, lack of training, and stakeholders' resistance to sharing data. However, all the respondents also acknowledge that blockchain increases trust, auditing, and regulatory compliance when transparency is continuously broadcast across the supply chain levels. These findings support the idea that blockchain, as a multi-purpose technology, cannot be referred to as a single type of transparency facilitator. Although quantitative data confirm its predictive role, the qualitative experiences demonstrate the limitations in context and the necessity of adopting strategic coordination, ecosystem collaboration, and user training. The interrelation of this information provides manageable tips on embracing blockchain in the supply chains of sustainability-driven fashion.

CHAPTER V: DISCUSSION

5.1 Introduction

This chapter critically analyzes the study findings in positioning the results in the research objectives and relevant theoretical perspectives. The research aimed to evaluate the role and capabilities of blockchain technology in ensuring the enhancement of transparency and traceability in the fashion supply chain, upholding the Sustainable Development Goals (SDGs) and Environmental, Social, and Governance (ESG) commitments. This mixed-methods research combined quantitative data collected during a survey of 259 industry actors in the fashion supply chain with qualitative knowledge, garnered through semi-structured interviews conducted with some of the key stakeholders in the fashion supply chain, sourcing managers, compliance officers and the technology partners. Combining the two sources of evidence produced a complete picture of the impact of blockchain on business: quantitative research supported widely used ideas, and the qualitative one explained them and revealed the various motives of and factors that hinder adoption. Altogether, the results point to blockchain features, including data unchangeability, access to stakeholders, and traceability, that significantly impact the supply chain transparency. However, there are still substantial barriers, primarily related to financial costs, stakeholder awareness and institutional resistance, as reported. The discussion continues, and each of the four objectives of the research is discussed and compared with quantitative results and qualitative data. It applies Institutional Theory and Resource-Based View to explain the organizational, strategic, and regulatory processes that influenced the uptake of blockchain in sustainable fashion.

5.2 Evaluating Blockchain's Potential to Enhance Transparency and Traceability

The current research, using a composite critical evaluation based on the Institutional Theory and resource-based View (RBV), presents a more extensive, dualistic picture through a recognized beneficial range of the potential of blockchain with a demonstrated limitation in its application spectrum. This two-fold lens allows the research to show the external pressure of accountability and internal vantage points that strategic value to blockchain. The scientific and industrial studies highlight the possible role of blockchain technology in increasing the supply chain transparency and traceability within the fashion industry (Saberi et al., 2019; Wang et al., 2020).

The quantitative results support the theoretical potential of technology. Among the five key constructs, Blockchain Traceability Capability (BTC) and Supply Chain Transparency (SCT) had the strongest mean scores: 4.036 and 3.964, respectively. The findings of BTC and SCT contradict previous studies that ranked transparency and traceability at the highest ethical supply chain benefit levels (e.g., Kouhizadeh et al., 2021). Regression analysis also indicates the strongest predictors of SCT are Blockchain Data Immutability (BDI) and Stakeholder Data Accessibility (SDA), whose beta coefficients are 0.348 and 0.305, correspondingly, which means that the presence of impervious data in the blockchain and the ability of various actors to access the data are of utmost importance to substantive transparency. The same argument is made in Saberi et al. (2019), when the authors state that a decentralized ledger can strengthen trust by not allowing for the delay of committed data. Even though Smart Contract Automation (SCA) has a statistically significant effect on SCT (0.151, $p < 0.05$), its relatively low beta coefficient (0.151) and average score of 3.9 indicate a more controlled discussion of implementation obstacles; unlike Wang et al. (2020) and his focus on automation, which defines the disruptive potential of blockchains. This feature of smart contracts could be viewed as less appealing or dangerous, which might be associated with the ambiguity of the legal identity of the industry and the lack of standardization of the procedure of contract execution. However, it has been posited by Sunny, Undralla and Madhusudanan Pillai, (2020) that smart contracts substantially improve visibility within supply chains as they tend to be self-executing digital agreements that are entrenched within blockchain systems, and programmed to inevitably trigger and enforce actions on the basis of predefined parameters and conditions.

Transparency is a multidimensional capability rather than a single construct as suggested by high intercorrelations between it and the measures of the other constructs, such as 0.866 between the Behavioral Depression Inventory (BDI) and the Supply Chain Transparency (SCT) measure, 0.855 between the Supply Chain Digitalization Assessment (SDA) and SCT, and 0.851 between SDA and BDI. Notably, these correlations are not necessarily adopted patterns since, as a study indicates, this is not true regarding the study's findings. As high as awareness of the use of blockchain has been reported so far (more than 60 % of respondents were exposed to the technology), the percentage of blockchain being implemented into fashion supply chains is still at 34.7 %.

These patterns are further clarified by complementary qualitative information from semi-structured interviews with industry practitioners. Participants have always singled out trust and data immutability as the most revolutionary attributes of blockchain. A sourcing manager pointed out that he feels accountable because he knows no one will tamper with the data between the farm and the factory, supporting the quantitative data collected on BDI. However, the interviews also present ongoing challenges in spreading blockchain among fashion supply chains' second and third ends. Some respondents cited low digital infrastructure, especially among providers of raw materials and finishing units that were subcontracted. The reported finding is consistent with Choi et al. (2020), who mention poor supply chain digitalization as one of the key obstacles to blockchain scalability in developing economies.

The interviews also highlight a conflict between centralized governance systems that have always been present in the fashion industry and the decentralized culture that is fundamental to blockchain technologies. Although the stakeholders were typically enthusiastic about increased data transparency, most were unwilling to share sensitive data about operations with competitors or non-governmental organizations. This feeling portrays the matters that may affect the firm's reputation or competitiveness. In fact, despite a high degree of perceived advantage concerning smart contracts, several interviewees highlighted the possible lack of flexibility in the code and litigation risks in case of contract failure. This aspect does not fit the technologically more positive literature (e.g., Kamble et al., 2021). Combined with the other results, those findings suggest that in an industry in which ethical, environmental, and reputational concerns are critical, automation tools that utilize smart contracts without implementing firm legal protection can leave firms more susceptible to liability than profits.

An Institutional Theory-informed critical analysis of recent blockchain projects in fashion will demonstrate how organizations react to normative, coercive, and mimetic pressures that increase legitimacy (DiMaggio and Powell, 1983). Modern research conducted by Henninger et al. (2021); PwC (2022) shows that fashion companies, including H&M, Zara, and Gucci, are today faced with an ever-increasing number of Environmental, Social, and Governance (ESG) obligations, consumer activism, and investor pressure. These stakeholders' needs have led to a more supportive environment towards greater adoption of the blockchain approach to supply chain transparency and accountability. However, the existing evidence shows that adoption at other times is essentially a symbolic, non-systemic product. Most companies make small pilot projects with technology providers, mostly IBM and Everledger, often to satisfy the stakeholders, but delay meaningful reorganization of operations because of perceived risk and complexity. The latter trend confirms the assumptions set forth by Huo et al. (2021), which state that fashion corporations are sticking to the emergent technologies in fragmented fashion to gain exterior legitimacy instead of re-engineering the inside systems. Interviews support this data, showing that many companies are still utilizing older systems, i.e., third-party audits and Commitment Logs based on PDFs, thus dulling the impact of what they expect to bring to real-time monitoring, which is decentralization. As a result, the perceived potential of blockchain is fundamentally the result of institutional theatre as much as it may be the product of technological possibility.

The Digital Product Passport (DPP) of the European Union under the Eco-design of Sustaining Products (ESPR) regulation is a centrally governed, legally binding process of transparency of sustainability in fashion supply chains. Apart from much growth of blockchain-based initiatives being out of the private sector and the push of stakeholders, the DPP is institutionally prescribed and in line with the broader Circular Economy Action Plan and the Green Deal of the EU (EPRS, 2024). Though giving legitimacy, such a regulatory push is nevertheless subject to the same symbolic propensity as early blockchain adaptation: the DPP leverages manufacturer-entered data with little third-party examination, ultimately undermining real-time traceability or immutability that a blockchain framework entails (Worldly, 2023). Simultaneously, stakeholders consulted through this study indicate the DPP's technocratic nature and non-responsive data application and argue its inability to support post-consumer tracking or foster relational trust. This kind of criticism is opposed to the blockchain-driven models, such as the Aura initiative of LVMH and CircularID, which allow participatory transparency and can dynamically trace resale, reuse, and recycling cycles. However, blockchain tracking has potential legal ambiguity and technical complexity issues, and the standardized compliance mechanisms may permit more widespread adoption, including in relatively regulatory-dominated societies. The comparative examination indicates a paradox: blockchain results in technological advantage in traceability and stakeholder empowerment, but the DPP benefits from institutional control and minor systemic interference. To this end, a two-tier approach involving blockchain verification alongside DPP-compliant data networks might be required to qualify the policy constraint with the functional visibility.

Applying the Resource-Based View (RBV), blockchain can be conceived as a strategic resource that improves a competitive advantage by providing sustainable sourcing, real-time tracking and stakeholder trust, particularly when they are rare, hard-earned, and not easily replicated (Barney, 1991). This view is corroborated by quantitative findings that show high reliability scores (Cronbach's Alpha = 0.87) that yield internal consistency with blockchain-related capabilities.

The qualitative narratives, however, complicate this interpretation. The availability of blockchain technology is also unequal: companies with high IT budgets and competent labor are better positioned towards getting value out, and SMEs or suppliers in developing countries face high barriers to adoption. As one technology supplier observed during an interview, such disparities are enhanced by the fact that it may work well for big brands to qualify their credentials using Blockchain, but what about their upstream suppliers, who do not have internet access? These asymmetries highlight the RBV approach's deficiencies that necessitate a more comprehensive framework that includes relational and ecosystem-based resources. The discussion also states that the potential of blockchain tends to be exaggerated, especially when the prospect of automation is presented as a help-all. Smart contracts, which are often considered the technological backbone of blockchain-based applications, show only partial trust between parties due to their rigid nature and the persisting lack of legal clarity. As Lacity and Van Hoek (2021) posit, Blockchain success is contingent not only on technological innovation but also on institutional fit, legal evolution, and stakeholder collaboration.

The findings obtained through this research reaffirms that blockchain has a substantial scope to reinforce transparency within fashion supply chains, mainly based on its characteristics of data immutability and accessibility to stakeholders (Kingfisher *et al.*, 2025). The said features have turned out to be the strongest forecasters of perceived transparency within the quantitative analysis. Nonetheless, embracing the technology continues to be restricted to pilot projects, which reveals a gap between the conceptual promise of blockchain and the level of its practical integration. It is possible to elucidate this pressure based on the dual lenses of the institutional theory and the RBV. While pressure might be driven by consumers and regulators, there is also pressure from investors wherein fashion organizations are forced to test blockchain to indicate signal legitimacy while lowering reputational risks (Caldarelli, Zardini and Rossignoli, 2021). At the same time, from the perspective of RBV, it has been emphasized that only organizations having substantial resources in terms of technology, capacity for governance, and skilled employees, will be able to forge ahead in a non-symbolic manner, towards strategic adoption. This offers an explanation on why large conglomerates are leading in blockchain-based initiatives while SMEs continue to be marginalized owing to restrictions on resources.

Furthermore, the findings obtained through this research add-on to the discourse on sustainability by indicating how SDG 12 and ESG operationalization can be facilitated with blockchain, based on data trials that are verifiable. Nonetheless, an absence of any standard metrics for sustainability tends to undermine the credibility of blockchain (Bhatt and Emdad, 2025), which exposes organizations to greenwashing allegations. From a practical perspective, the findings obtained here suggest that it is imperative that supply chain managers give priority to interoperability and inclusivity of stakeholders while structuring blockchain based solutions (Anthony Jnr, 2024). In the absence of engagement with upstream SMEs and suppliers, presents blockchain adoption risks embedding current inequalities instead of facilitating a systematic transparency. Thus, for scalable adoption, there is a need for a dual focus, one that aligns with pressures of institutional legitimacy while investing in internal capabilities that ensure sustainability results delivered through blockchain can be verified and measured.

5.3 Barriers to Adoption and Scalability

This research shows a few notable challenges that prevent the implementation and expansion of blockchain technology in the fashion supply chain, which is mainly focused on financial, technical, and cultural issues. The high initial cost of implementing blockchain technology was one of the main matters that were noted during the interviews. As stressed in quantitative analysis, a range of participants, especially those representing small and medium sized enterprises (SMEs) were concerned about the financial demands that are entailed to set up blockchain infrastructure. These firms are not always rich with huge financial capital to invest in the expensive requirements of blockchain such as the purchase of hardware, software development along with employee specific training. This is similar to the findings of other authors (Saxena et al., 2022; Vaghani, 2024) regarding the initial setup costs, which serve as one of the first blocks to the adoption of blockchain as a solution, at least in companies located in developing markets or those with less capital. However, it was discovered that the luxury industry was in a much better position to deploy such expenses, especially when such investments involved chains such as the Aura Blockchain Consortium initiated by LVMH, which was hailed by the participants of the chain as one that would provide transparency and traceability. The stories of these luxury brands, however, cannot be simply repeated to the fashion industry with much mass production, and much less profit, and hence block chain implementation is not financially sound.

The second important obstacle mentioned by participants was the absence of technical knowledge that is needed to be able to implement and maintain blockchain systems. This concern was especially true to smaller companies and firms in the developing region, where there is usually a gap in skills of blockchain technology. As indicated by numerous respondents, the ease with which blockchain technology could benefit the industry has not been matched by the ease of acquisition of qualified blockchain professionals thus delaying the industry. This only goes in line with the observation made by Kshetri (2018), who observes that the blockchain technology requires special knowledge in order to execute appropriately, and this lack of professional expertise is a major challenge. Moreover, the compatibility with the available systems, i.e. Enterprise Resource Planning (ERP) systems, has also been a complicated and expensive process. Another aspect that makes blockchain adoption even more daunting is that conventional systems need to be restructured or radically changed to accommodate it. This can be seen in the findings, whereby the study found that numerous participants were frustrated about the fact that block chain could not be integrated with traditional systems such as SAP or Oracle which are currently very popular in the fashion industry to manage their supply chain.

In addition to technical and financial factors, it was mainly related to cultural obstacles in accepting new technology that was mentioned by the participants. The results have revealed that the most part of an organization in the fashion industry is reluctant towards using blockchain since the industry as a whole is not willing to accept technological change. Specifically, the companies owned by families and older firms within the fashion industry were found to be largely resistant to the replacement of traditional working processes by the technology of blockchains. This was attributed to fear of disturbance in the already established processes and institutional inertia. The cultural barrier where cultural resistance was identified in the results reflects the study by Sayilir et al. (2025), who provide the argument that organizations are reluctant to change towards using new technologies due to being trapped in the current way of doing things and management structure. Besides, a significant number of employees were found to be hesitant to embrace blockchain since they lack conceptual knowledge and exposure to the technology. The steps to counter this resistance to change will not be merely to invest in education and training but also to come up with change management strategies to answer resistance to change not only in the organization but also to employees.

Scalability of blockchain technology also stood out as an important subject matter of this research. These results showed that blockchain could be viable to luxury brands or small-scale uses but not large-scale fragmented supply chains within the mass-market fashion industry, which was a challenge. A participant mentioned that it is a complex effort to coordinate the various parties in the supply chain to scale blockchain, and this may be challenging because of the geographical and organizational distances. It is in line with the study presented by Vaghani (2024) that outlines the challenges of scaling blockchain in pilot projects to full-scale adoption within the wider industry, specifically in areas with more complex and less central supply chains, such as fast fashion.

5.4 Real-World Applications and Case-Based Practices

The practical implementations of blockchain technologies in fashion industry can provide important lessons in what is possible and what is not possible with blockchain technology. There are some essential case studies that are conducted in this research, and they gave a better picture on the way blockchain has been applied practically and what are the impacts on supply chain activities. Another famous story about LVMH Aura Blockchain Consortium presented by participants is another bright example of one of the first attempts in the luxury fashion industry to enhance product authenticity and transparency. According to the results, using Aura Blockchain offers the possibility of tracking products to their source in raw materials to retail store; consumers can then get considerable detail on the origin and origin of their purchases. This can be done by using QR codes where one can ascertain, in real time, the history of the product so that those claiming authenticity and sustainability can be caught. The advantages of the Aura Consortium were understood well among the participants, specifically, in regard to consumer trust, as well as brand credibility which both increased immensely due to blockchain-enabling transparency.

Nonetheless, the scalability of blockchain solutions, such as Aura Blockchain, to the high-end fashion business is problematic even though it works well in the luxury industry. Surveyed participants have added that luxury brands have been able to embrace blockchain since they serve an exclusive tier of consumers who focus on brand authenticity and transparency of products. Conversely, mass-market fashion companies under pure profitability factors and significant volumes of production find it hard to deploy blockchain on a corresponding level. This issue has also been magnified by the fact that there are high initial investment costs when it comes to adopting blockchain, which have also been brought out in the findings. Consequently, the high-end industry has been better able to make the shift to blockchain technology than the mass market where issues relating to scalability restrict the popularity of the technology.

The other notable case study that was mentioned in the results was the collaboration of IBM with the German fashion manufacturer Kaya & Kato dedicated to the work with blockchain, which was meant to enhance their sustainability efforts in the supply chain. The project would trace the raw materials used in the production of uniforms and ensure that every part met the requirement of sustainability. Although this project made it clear the opportunities that blockchain potentially has to offer a supply chain in better tracking of its environmental impact, the interviewees of the study noted that scaled-up initiatives like this to mainstream fashion brands are full of pitfalls. Challenges posed by high implementation costs are not the only ones but also the requirement of sufficient advanced digital infrastructure and possibility of integrating blockchain into other existing system of supply chain management. This result can be related to Gariba et al. (2024), who state that a major blockchain implementation in a high-volume-producing industry such as fashion is still limited due to financial concerns and technical challenges.

Besides, findings demonstrated that the issue of gaps in visibility in supply chains is a serious concern in most fashion firms. It is emphasized by the participants that although blockchain is used in pilot projects, real-time data exchange, tier-based supplier visibility, and last-mile tracking is not addressed in certain supply chains. This is especially because in fast fashion brands the supply chain is wide, and the sourcing is all over the world hence full supply chain visibility is hard to achieve. Such results synchronize with Queiroz et al. (2021) who state that real-time monitoring and interorganizational exchange of information are the key to maximizing the potential of blockchain. In the absence of these abilities, the potential of blockchain in enhancing transparency of the supply chain is greatly effective.

5.5 Blockchain Transparency and Sustainability Alignment

The results of the present study indicate that blockchain technology has great potential in terms of enhancing transparency and sustainability of the fashion industry. The nature of blockchain, being incorruptible and transparent records of movements and incidences in transactions acts as a perfect solution to some of the most urgent sustainability issues in the fashion supply chain. According to the study participants, there are a number of ways through which blockchain increases the transparency in the supply chain and aids the companies to meet the requirements of sustainability. To illustrate, real-time monitoring of raw material, and the production process allows companies to present accountable evidence of sustainable supply chain and work ethics, which is also insinuated by consumers and the law.

Additionally, the results of the study also indicate that environmental standards and norms related to carbon emissions and water consumption throughout the supply chain can also be fulfilled with the help of blockchain. This can be done by employing smart contracts and IoT sensors on the blockchain allowing businesses to stay aware of the environmental impact of every action in their production process. This functionality goes hand in hand with SDG 12 (Responsible Consumption and Production), since it is possible to provide real-time checks and sustainability reporting automation with the help of blockchain. The verifiability of blockchain data guarantees that, companies can make verifiable sustainability claims that are credible and therefore ensures that companies face less risk of greenwashing and it will raise their reputation among the consumers and the stakeholders.

The study further established that blockchain technology is useful in ensuring social sustainability with companies having access to reliable information about labor conditions and pay through the supply chain. The contributors observed that the secure ledger system facilitated by blockchain would allow companies to certify labor standards, which would make workers be paid their fair share and their rights to be recognized. This is vital especially in areas where there is labor abuse like child labor or risky working environment. Through tracing all the steps of the supply chain, Blockchain enables both consumers and auditors to have verified information regarding social compliance, which is one more point that makes blockchain and ESG goals compatible.

These results advocate the ideas expressed in the literature review, especially those by Kshetri (2018); Saxena et al. (2022), who gathered insights on how blockchain can add more transparency and traceability to the fashion supply chain. Blockchain allows fashion companies to achieve sustainability goals and ESG because it can attain verifiable information concerning the origins and materials sourcing of their products and their production processes. The results are also close to those found by Shukla (2025) who emphasizes the rise of consumer curiosity to trust verified sustainability claims, and a trend towards ethical sourcing being increasingly relied upon as a condition of fashion buying.

5.6 Comparison of Blockchain Solution with DPP

The blockchain-based solution that has been proposed in this research presents significant benefits as compared to DPP, mainly owing to blockchain's tamperproof and decentralized architecture. As compared to conventional DPPs, that are known to largely depend on semi-centralized or centralized systems which is susceptible to delayed updates and manipulation of data, the approach proposed through this research offers real-time traceability and immutability over all nodes of supply chain (Bischoff and Seuring, 2021;Kim *et al.*, 2025). Incorporating smart contracts facilitates auditability, compliance, and allows ESG-related rules to be applied, which brings ins a greater level of efficiency and trust, than DPP data which is manually updated (Hulea, Miron and Muresan, 2024).

The solution proposed through this research is inclusive of mechanisms for preserving privacy, such as zero-knowledge proofs and selective data sharing, which enables organizations to adhere to transparency requirements without revealing any commercial information that is sensitive in nature. This kind of a balance is seldom provided by DPP (Domskienė and Gaidule, 2024). In addition, by harnessing the potential of distributed file systems such as IPFS in parallel with blockchain, the proposed blockchain solution tackles the issue of storage scalability which is one of the fundamental limitation of several DPP implementations (Kim *et al.*, 2025).

To sum it up, the proposed solution overcomes the shortcomings of DPPs by blending automated governance, scalable data management, immutable traceability and privacy safeguards, which enhances the superiority of blockchain for resilient, authentic, and sustainable transparency within supply chains.

In order to deploy the blockchain solution in an effective and successful manner, a collaborative and phased approach needs to be adopted. During the preliminary phases, fashion organizations should execute pilot projects with a clear focus on supply chain segments with high risks (labor compliance or sourcing raw materials), incorporating digital reporting tools and IoT sensors for ascertaining authenticity of data. At the same time, onboarding stakeholders which is inclusive of auditors, SMEs, and regulators are necessary, and can be realized through incentive schemes and training workshops which not only stimulate data-sharing but also lowers resistance. In the next phase, the focus should shift to interoperability of systems, which facilitates incorporation with legacy ERP systems and also frameworks such as the EU CSRD. Lastly, in the final phase which warrants large scale deployment, it must include smart contracts for automated ESG compliance, in tandem with governance mechanisms for selective data disclosure for safeguarding commercial confidentiality. Thus, a three-phase strategy would be instrumental in ensuring scalability while lowering disruption and places the blockchain solution as an infrastructure which is future ready, enabling verifiable and sustainable supply chains.

5.7 Limitations and Areas for Further Research

5.7.1 Limitations of the Study

There are a few limitations that should be noted but even though this research can offer some answers regarding the barriers and the uses of blockchain in fashion supply chain, there are some restrictions that one should mention. Among these major limitations is the geographical orientation of the study. Despite the fact that there was an investigation of findings such as luxury brands and small to medium-sized enterprises (SMEs), the study is mostly focused on the participants operating in the developed markets. This constrains the overall applicability of the results to areas deploying blockchain technology at a lower level or those with infrastructural issues. As the literature notes, poorly developed technological environments can become an even insurmountable obstacle to the use of blockchain technology, especially in obsolete or already manual supply chains (Kshetri, 2018). Therefore, this study might be applied to the field of further research on the emerging market in which the rates of technology adoption are significantly different.

The contents of the blockchain applications represented in the study is the other limitation. Although the study examined the topic of luxury brands as well as certain pilot projects using blockchain in the fashion industry, the implications of blockchain in the fast fashion industry as a whole were not thoroughly covered since it is affected by some special considerations, such as a high turnover of production and a lower profitability rate. The opportunity of blockchain to improve supply chain transparency and ethical sourcing at this level is also unexploited. Based on the research findings, financial and technical limitations of fast fashion brands might imply that the use of blockchain technology in this field can be slower and more complex than in the case of luxury brands. This is a problem as Gariba et al. (2024) note that scalability is an open issue within the low-cost fashion industry and further studies should be conducted to look into blockchain applicability to this industry.

Also, the research was based on quite extensive qualitative data collected in the form of interviews, which, on the one hand, introduce detailed information to individual perceptions and experiences, and on the other hand, it may not represent the whole industry. The scale and sample groups used in choosing the participants could also be a limiting factor towards the thoroughness of the results. The researchers should consider including more extensive diverse samples of the professionals of the industry, such as supply chain managers, blockchain developers, and consumers in the future study to have a full picture of the challenges and opportunities linked to blockchain in fashion.

5.7.2 Areas for future research

Based on findings established in this study, it is possible to identify a number of areas that require a need to conduct additional research to overcome the challenges and the opportunities posed by blockchain in fashion supply chains. Scalability is one of the most relevant problems first. Whereas blockchain is promising in pilot programs, scaling blockchain solutions to the whole supply chain of the mass-market fashion business is not an entirely clear picture yet. Further studies on finding technical and financial opportunities that would increase blockchain beyond luxury brands to smaller firms and fast fashion companies may arise in the future. Scientists might explore how to devise cost-effective, more-plastic blockchain applications that would fit the particular needs of large-scale, low-mark-up industries.

Integration of blockchain in the current supply chain systems is also another research area of concern in the future. As the results indicate, there are the existence of legacy systems, such as SAP or Oracle, which do not work with a blockchain, and this poses serious challenges to their adoption. In the future, researchers might explore the possibility of an effortless blending of blockchain with conventional Enterprise Resource Planning (ERP) solutions and inventory systems. Also, the topic that can be investigated is the interoperability standards and open-source blockchain solutions that will not require companies to make significant changes to the pre-existing systems to realize blockchain.

Moreover, the problem of regulations and legalities of the blockchain adoption in fashion supply chain should be discussed in the future. The possibility of achieving greater transparency and traceability by means of blockchain leads to the concerns of data privacy, protection of intellectual property, and adherence to the rules of the regions. The potential to exploit the blockchain in order to align with regional and international legislation, like the EU Corporate Sustainability Due Diligence Directive (CSDDD), or the Modern Slavery Act (2015) in the UK, are all areas that can be researched by researchers. Reading every day about the trend of ethical sourcing and green standards in the fashion industry, it will soon be crucial to learn how blockchain can allow companies to fulfill their duty to perform according to these requirements without violating data protection legislation.

Finally, a study can be conducted on how consumers are regarding blockchain adoption in fashion. Although the research mentioned consumer demand with regards to the transparency of sustainability, the paper does not venture deeply on the way in which consumers use the elements of blockchain-enabled transparency, including QR codes and digital product passports. The knowledge about the consumer-blockchain product information interaction and the ways it affects the purchase behavior may assist companies in the development of blockchain systems that would be consistent with consumer expectations and encourage them in becoming sustainability agents.

5.8 Conclusion

This research enlightens the problems, uses, and the prospects of sustainability of the blockchain technology in the fashion supply chain. The results reveal that although blockchain has evident advantages to enhancing transparency and traceability of the supply chain, most implementations of blockchains are held back by a number of obstacles, such as high implementation costs, insufficient technical skills, and cultural opposition in firms. Examples of such barriers are especially high in the case of small and medium-sized enterprises (SMEs) and mass-market fashion organizations, as they experience certain challenges concerning the adoption of blockchain technology.

The fact that blockchain corresponds to SDG 12 (Responsible Consumption and Production) and ESG objectives creates additional potential in enhancing the sustainability of fashion supply chains. The results of this research support the significance of blockchain in the area of monitoring carbon emissions, water consumption, and compliance with the ethical labor standards, thereby enabling companies to achieve environmental and social sustainability goals. To realize such a potential however, it will be necessary to eliminate the financial, technical and cultural challenges identified in this research.

CHAPTER VI: CONCLUSION

The final chapter summarizes the study's key conclusions that explore the potential of blockchain technology to promote transparency in the fashion industry's supply chains, along with complying with the goals of Sustainable Development Goal 12 and ESG practices. The chapter synthesizes the knowledge created by empirical assessment using a mixed-method design guided by the theory of institutions and the Resource-Based View. Practical stakeholder recommendations are also provided, and the potential of blockchain in sustainable fashion is assessed, along with the boundaries of additional research. In the process, it reconfirms the strategic significance of blockchain in the light of the changing regulatory and industry environment.

6.1. Summary of Findings

The study questions whether blockchain technology could strengthen supply chain transparency in the fashion industry and align with Sustainable Development Goal 12 (Responsible Consumption and Production) and Environmental, Social, and Governance (ESG) systems. Employing mixed-methods design, a combination of quantitative survey-static and qualitative interview data, the study provides evidence that blockchain can be viewed as a credible, scalable, and future-resistant tool that can address many transparency and traceability gaps within the international fashion supply networks. The empirical results validated the conceptual model developed in terms of the Institutional Theory and the Resource-Based View (RBV), providing a unified explanation of the external stressors and internal facilitating factors in the context of blockchain adoption.

Four general technological characteristics of blockchain technology are traceability, immutability, smart contracts and decentralization of data access, which elevate transparency into complex, multi-tiered supply chains. The most important advantage has been listed as traceability, which will allow companies to track garments and raw products at all supply chain levels. The participants stated that traceability has become essential in assuring sustainability claims, operational risk governance, and regulatory compliance. The immutable blockchain technology cannot alter or delete information once recorded, thus offering a safe environment for ESG reporting and stakeholder assurance. Smart contracts also enhance operational integrity because they automate checks of ESG compliance, and only compliant transactions are allowed. Besides, the decentralized access framework of blockchain enables stakeholders, suppliers, regulators and consumers to access confirmed data in real time, strengthening transparency and responsibility.

Based on empirical evidence, the technological capabilities of blockchain, such as real-time tracking and reporting of carbon footprints, energy consumption, and waste production, can be directly used to achieve SDG 12 and ESG goals. Environmentally, blockchain would enable integration into IoT devices, enabling systematic, non-stop monitoring, eliminating data availability gaps and improving reliability. On the social front, blockchain will offer a tamper-proof ledger to store wage statistics, labor conditions and supplier certifications and reduce the likelihood of exploitative actions or poor working conditions lasting undetected. In a governance context, it makes compliance easier by making auditable, automated records, which reduces the need to use third-party checkers and older paper-based audit solutions. With increasing focus on ESG, blockchain infrastructure will allow organizations to provide consistent, similar and trustworthy data on sustainability to regulators, investors and consumers.

Institutional Theory offers a strict framework for analyzing the adoption dynamics in the fashion industry. As empirical evidence suggests, coercive pressures, namely legislative directives, including the EU Corporate Sustainability Due Diligence Directive (CSDDD), the UK Modern Slavery Act, and the impending requirements of the European Digital Product Passport (DPP), are forcing organizations to invest in technologies which facilitate better transparency into their supply chains. At the same time, normative pressure, such as industry requirements and ESG reporting frameworks such as GRI and CSRD, has made blockchain an acceptable, more-than-likely form of a solution to technological problems. Mimetic pressures drive adoption; as market leaders like LVMH, Adidas, and Stella McCartney have already experimented with transparency tools in blockchains, there is motivation to follow suit and share in the proven reputational advantages.

The Resource-Based View provides an explanatory perspective to assess how internal capabilities modulate adopting technology innovation. The empirical results reveal that, within the successive industries, organizations with access to a vast digital infrastructure, professional talent, and company leadership have a better ability to introduce blockchain-related undertakings. These types of organizations regularly have partnerships and agreements with incumbent technology suppliers; as such, IBM and SAP would be pertinent examples of such partnerships and agreements. In their turn, small and medium-sized enterprises (SME) also tend to face the problem of limited technical knowledge, financial funds, and digital readiness. The evidence, thus, posits that the effective adoption of blockchain is subject to strategic competence and proper investment, not external pressure alone. Organizational culture, an inclination toward innovation, and involvement in collaborative ecosystems appear to be powerful enabling variables.

Empirical case studies also support these observations. The Aura Blockchain Consortium, led by LVMH and other luxury brands, has tokenized over 30 million products, and consumers can access verified information concerning the product origin, manufacturing processes and sustainability features. According to the participants, this initiative strengthened the brand trust and credibility of ESG. Similarly, the IBM Kaya & Kato project in Germany exhibited the potential of blockchain technology in textile-sourcing traceability and supplied to the government requests. These pilots demonstrated transparency, measurable improvements, and identified resistance areas like supplier digital readiness, existing system incompatibility, and the cost of adopting disparate provider networks. Though both pilots' feasibility and strategic value are evident, economic and technical problems limit their scalability to the rest of the fashion industry.

A survey of current efforts shows several long-term barriers to blockchain adoption. The first reason is the high costs associated with its implementation, and the second significant obstacle is the absence of globally consistent environmental, social and governance (ESG) indicators. In the absence of common reporting frameworks, blockchain systems have disparate data quality and, thus, a lack of utility in comparison, benchmarking or regulatory compliance. Many businesses refuse to share specific supply chain concerns because of reputation, fears of transferring competitive advantage, or even fear of facing regulatory inspection. Another challenge is technical complexity and related data privacy issues, enhanced by various regulatory frameworks in multiple jurisdictions. Resistance by some organizations to digital transformation and a lack of the necessary skilled workforce, especially among small and medium-sized organizations and corporations in their initial phases of sustainability adaptation, adds a further limit.

The current work considerably compares the blockchain with the Digital Product Passport (DPP) proposed by the European Union against the Eco-design for Sustainable Products Regulation (ESPR). The DPP is designed to gather and openly publish environmental and social data of consumer items using a centralized, standardized approach that could be reached via QR codes or digital labels. Although the proposal constitutes an advancement with significant efforts to create product-level transparency, it is suggested that its centralized design and narrow EU-centric focus will limit its scope. More importantly, blockchain is a decentralized, flexible, scalable solution that can handle the fashion industry's globalized and fragmented supply chain. Responses from interviewees, particularly those with industry and technology backgrounds, indicate that they were concerned the DPP would struggle to integrate small suppliers in disadvantaged areas or maintain data integrity in extensive and intricate supply chains. Blockchain solves these problems, as it can share data in real-time and without complete integration into a centralized system in an irreversible manner. Moreover, its ability to automate ESG certification using smart contracts and encourage cross-jurisdictional interoperability qualifies it as an alternative or complementary tool to the DPP in most scenarios. The results indicate that blockchain may facilitate or become a standalone infrastructure for companies outside the EU governance.

6.2. Recommendations

The current recommendations are based on empirical evidence and are formulated based on the overall aims of this research, namely, to explore the possibilities of how blockchain can promote transparency in the fashion supply chain, the ESG and SDG 12 initiatives, and position itself advantageously in comparison with other frameworks, like the European Union Digital Product Passport (DPP). These are directives to industry practitioners, policymakers, and technology developers interested in changing global fashion supply chains.

Instead of implementing blockchain throughout their operations, fashion companies should follow a step-by-step approach, starting with risk-based implementation. This research report suggests that incremental pilots (especially those with high-risk suppliers or environmentally sensitive materials) have more success in the success scale in terms of operational feasibility and internalization. This conclusion coincides with that of Jiang et al. (2021), who suggest that fragmented industries are more viable to implement modular blockchain since it is more sustainable. A risk-based rollout will focus and prioritizes resources in areas where transparency gaps have the highest leverage on ESG or regulatory risk, where companies can then test, adapt and scale down based on contextual responses (European Banking Authority, 2025).

Experience has demonstrated that the nature of blockchain is even more radical when it can be incorporated in an infrastructural cooperation framework. As proven by Rossi et al. (2020), consortia like Aura Blockchain Consortium minimize operational costs, prevent redundancies and encourage interoperability between brands and tiers. However, to achieve distributive equity, these institutions should include small- and medium-sized firms, suppliers in the Global South, non-governmental organizations, authorities, and large multinationals. Inclusive governance structures are hence necessary to prevent the continuation of the existing power imbalances. Sharing standards, access rights and using open-source platforms all help enable collaborative innovation, thereby avoiding the risks of vendor lock-in and centralization of control (Chen and Zhou, 2025).

However, the lack of consistent definitions and measurement systems of ESG limits the use of blockchain in sustainability reporting. Raleigh, Kishi, and Linke (2023) explain that data immutability is valuable only under reliable and standardized inputs. Without common standards, blockchain-enabled information is hard to compare among businesses and jurisdictions, undermining its effectiveness in due diligence and governance audits. The authors also highlight the risks of storing inconsistent or unverifiable data in permanent records. Regulatory authorities (e.g., EU Commission) and standard setters (e.g., GRI, ISSB, UNEP FI) must collaborate with blockchain developers to make technical protocols when harmonized with international ESG reporting standards and expected DPP guidelines.

Blockchain is often promoted as a decentralization tool; however, a lower-tier supplier is often locked out due to technical and economic barriers. As this study revealed, many suppliers in South Asia and sub-Saharan Africa do not have the necessary digital infrastructure or training to play a role in blockchain-enabled systems. Without systemic contribution, data gaps are created, which hinder traceability. Rejeb et al. (2021) insist that the future success of blockchain lies in the digital readiness and collaborative interaction of all supply chain players. Based on that, brands and NGOs should collaboratively develop supplier-enablement programs like hardware supply, Blockchain-based training, and multilingual support systems to enable purposeful engagements. These actions align with ethical sourcing regulations and create equal technology utilization.

Instead of considering blockchain technology as an alternative to traditional, state-based compliance mechanisms, it should be viewed as a facilitating infrastructure that can evolve with emerging legal needs. The EU Digital Product Passport (DPP) under the Environmental Sustainability Package (ESPR) exemplifies this: the proposed centralized reporting system will likely face scaling challenges in globally distributed multitier supply chains. Based on empirical data, the current paper shows how blockchain's inherently decentralized, real-time architecture can overcome these restrictions by enabling dynamic and tamper-proof compliance tracking. Following Erlingsson, Thomasson, and Ohrvall (2018), the hybrid regulation model, incorporating both the public regulatory model and decentralized digital tools, seems to promote transparency and accountability. Therefore, the policymakers are advised to incorporate blockchain features in the workflow of the DPP, especially in data input verification and cross-country SME inclusion.

Blockchain is not a plug-and-play solution; its effectiveness lies in strategic integration with sustainability objectives, procurement policies, and stakeholder governance. This paper revealed that companies that integrated blockchain into their ESG strategies and ethical sourcing requirements yielded higher reputational and operational benefits than those that implemented it as an addition to compliance. Resource-Based View implies that the value is created when companies incorporate new technologies into their operations and strategic abilities (Furr and Eisenhardt, 2021). This aligns with the finding of Teh et al. (2020) that blockchain sustainability potential is optimized when embedded in a holistic approach to corporate responsibility encompassing lifecycle assessment, human rights due diligence, and environmental stewardship. Overall, blockchain implementation in fashion should be responsive to institutional needs and organizational capabilities, promoting collaboration, inclusiveness, and governance to translate pilots into scalable solutions that resonate with SDG 12 and ESG objectives.

6.3. Future Implications

The possibilities of blockchain technology to disrupt supply chain transparency within the fashion industry reach further than the strictly technical benefits. These findings are far-reaching, and they are significant considering the increasing need to infuse sustainable fashion and corporate responsibility. With organizations either trying to achieve Sustainable Development Goal 12 (SDG 12) and Environmental, Social and Governance (ESG) criteria, blockchain is a priceless resource that can be used to ensure authenticity, traceability, and accountability within the supply chain.

Among the most important implications brought about by this study is that it can be used to increase transparency in chains that are complex and multi-tier. The study concluded that blockchain had the potential to give real-time monitoring over raw materials, final products and sustainability ratings. This is specifically applicable in combating problems with counterfeiting, greenwashing and its labor exploitation which resonate critically to the consumers, regulators and investors. Blockchain uses an immutable ledger, and once the data has been entered, it cannot be changed, and this is a critical aspect in case of ESG reports. Including blockchain means that organizations will be able to offer a clear and non-revision able record of each and every product, between its creation and its sale, thus guaranteeing consumers and other stakeholders that the sustainability ones are authentic. With both the general population and legal frameworks exerting more and more pressure on the fashion industry, blockchain can play an important role in ensuring that the fashion industry can keep abreast of the changing expectations.

Also, another effective implication of blockchain technology is that it enables auto-compliance via smart contracts. The results showed that smart contracts may be used to make sure that only the compliant suppliers are accepted into the supply chain. It implies that any party that cannot provide sustainability standards or ethical standards would automatically be locked out of the chain to form a stronger and ethical supply chain. Businesses, particularly those in the luxury fashion and high-end brand industries, can take advantage of this aspect to make sure they are within the high standards of the new regulation like the EU Corporate Sustainability Due Diligence Directive (CSDDD) or the Modern Slavery Act in Great Britain. Automated compliance systems that blockchain offers may eliminate manual reviews and third-party audits, and less administrational expense and human mistakes.

Of this study there is also the implication of working initiative. The study indicates that implementation of blockchain in fashion cannot be perceived as an initiative by a single brand or a company but as a community of stakeholders, such as suppliers, NGOs, regulatory agencies, and providers of the technology. The collaborative infrastructure is the most probable requirement of the future supply chains and blockchain can best provide it. This decentralized characteristic of blockchain provides that the data is not subjected to the authority of a single organization or entity and increases sharing of data and interchangeability of different partners within the supply chain. This is hugely promising in terms of creating more inclusive governance systems, not least in the incorporation of small and medium-sized enterprises (SMEs) and suppliers based in developing regions as well as non-governmental organizations (NGOs) into the blockchain system.

Also, economic costs of blockchain adoption in the apparel and fashion sphere are significant. Blockchain implementation will be initially expensive, but the overall efficiency, reduced costs, and the mitigation of risks in the long run can offer a good return on a long-term investment. Blockchain is able to automate numerous manual procedures that include inventory, auditing, and reporting, limiting the requirement of intermediaries and third-party auditors. In the long term, it can result in reduced operational expenses, mainly among the businesses that implement blockchain on a large scale. Nevertheless, to get the most of these opportunities, companies will also need to invest into digital infrastructure and training of employees so that they are able to acquire technical capacity necessary to adopt and sustain blockchain systems.

The research also refers to the fact that blockchain will influence the development of sustainable fashion in the future. The fact that consumers are increasingly demanding products with an ethical production and environmentally friendly background is steadily increasing the significance of blockchain to demonstrate sustainability across all supply chain stages. Organizations, which are able to provide customers with verifiable confirmation of their sustainability practices, will almost certainly hold a competitive edge in the marketplace. Blockchain might therefore serve as a game changer in the fashion industry, making it a totally new paradigm of opacity and exploitation to transparency, trust, and accountability. The companies that use artistic tools to adhere to regulatory standards and, at the same time, do not neglect the ethical values of both consumers and investors, may turn out to become the future of the fashion industry.

6.4. Future Research Directions

Though this research has yielded convincing information on areas where blockchain technology can be applied in fashion supply chain, there are a couple of areas that can be explored by future researchers. These guidelines revolve around the current challenges and opportunities that blockchain offers and the overall integration of such technology in the ecosystem of the fashion world. The analysis of technical, economic, cultural, and regulatory implications of blockchain adoption should be conducted in the future when the sustainability implications of blockchain adoption in the long run will be further justified in the context of the fashion industry.

The scaling of blockchain solutions in mass-market fashion is one of the main areas covered by possible future research. This paper is a discussion on the possibility of blockchain in the luxury fashion industry, where products sold are products of high value, and afford the high upfront price of implementation. Nevertheless, the mass-market fashion sector is a specific industry because of the volume of production, low profitability, and the multinational chains used.

Future research on these industries should be done on how the blockchain can be more economically and scalable. Researchers might examine the technical modifications that should be made in order to use blockchain among a vast multitude of suppliers and different processes of production in industries characterized by great volumes and little profitability, such as the fast fashion industry. The research of hybridized blockchain approaches, having centralization and decentralization functionality, could provide some answers regarding the topic of the balance between cost, efficiency, and scalability in a market-wide environment.

The second important line of research follows the ability to combine blockchain with current supply chain technologies. As shown in the research, there are still a lot of companies in the fashion industry that are using legacy systems like Enterprise Resource Planning (ERP) systems (e.g., SAP and Oracle), and the deployment of blockchain with the legacy system has been challenging in terms of technology. The topic that can be further researched is associated with applying interoperability frameworks enabling integrated utilization of blockchain systems with the capabilities of current supply chain management technologies. The researchers are required to carry out a study on how the decentralized data structure in blockchain can be successfully meshed with the conventional traditional centralized system used in procurement, logistics and inventory tracking.

Additionally, the aspect of data privacy and security of blockchain adoption is an outstanding issue, especially to the fashion industry where important data of suppliers and clients, as well as businesses, ought to be safeguarded. The next steps of research should be to investigate the transparency versus data security of blockchain systems. To secure confidential information, researchers may want to research privacy-enhancing technologies, e.g., zero-knowledge proofs, or permissioned blockchains, that would allow keeping sensitive data but would preserve the necessary transparency, in terms of ESG reporting and regulatory compliance. Studying the security issues and weaknesses that are inherent to blockchain platforms will also be relevant towards coming up with best practices in securing successful implementations.

Blockchain adoption also relies heavily on cultural factors. The characteristic that the study came across is that cultural resistance of blockchain, at least in the context of family-owned businesses and long-established firms, is a challenge. The field of future research may include the psychological and organizational determinants of decision-making concerning new technologies in the fashion industry. Researchers may investigate the influence of organizational culture and leadership approaches on the desire to migrate to solutions using blockchain. Also, the comparison between the fashion industry and other industries outside the fashion sector which have effectively incorporated the use of blockchain such as luxury goods or food safety may be able to shed some light on crossing over the cultural barriers.

Regulatory environment relating to blockchain technology continues to change especially focusing on sustainability and ethical sourcing. With regulation agencies exerting more pressure on fashion companies to align their fashion practices with the standards of sustainability, more research on how blockchain can facilitate the services of companies to engage the regulations agencies is required. Future research ought to establish some of the ways in which blockchain could be applied to regulatory regimes like the EU Digital Product Passport (DPP) or Eco-design of Sustainable Products Regulation (ESPR). These models, as desirable as they sound, can become limited in terms of achieving interoperability across jurisdiction and challenges to data sharing across jurisdiction. It would be helpful to understand more about how blockchain might support or supplement many of the current frameworks that one would be able to come up with good ideas in global governance and regulatory compliance.

In addition, future research needs to focus on consumer behavior towards blockchain transparency systems. The results of the current research indicate that blockchain technology can be used to generate consumer trust because it can support verifiable data related to the origin of products, their sustainability, and ethical labor conditions. Nonetheless, future studies should be conducted to determine consumer engagement with transparency-enabling tools that can be used on blockchain, e.g., the QR code or digital product passport. It is expected that future research examines the changes that occur to consumer behavior in the context of blockchain transparency and whether the ultimate benefits of growing trust translate into more sustainable purchasing choices. Identifying what drives the adoption of blockchain transparency tools by the consumers will be critical to the brands aiming to leverage on this technology in a consumer-centric market.

Lastly, there should be research to determine the possibilities of such a solution as blockchain as a developer of circular economy models in fashion. Circular fashion- concerns reuse, repair, refurbishment and recycling and is a trending model in line with the sustainability objective. Blockchain has the potential to be important in measuring the lifecycle of clothes, including production and end-of-life recycling, so that products will be able to be traced and recycled more efficiently. Exploring the potential of blockchain in the enabling of circular fashion activities may present fresh possibilities of innovation in the field of sustainable fashion.

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APPENDICES

APPENDIX A: SURVEY QUESTIONNAIRE

Dear Participant,

This survey aims to investigate how blockchain technology contributes to enhancing supply chain transparency in the fashion industry, specifically in alignment with Sustainable Development Goal (SDG) 12 and Environmental, Social, and Governance (ESG) frameworks. Your responses will be used for academic research purposes and will remain confidential.

Section 1: Demographics

1. What is your current job role?

1. Sourcing Manager
2. Planning Manager
3. IT Application Manager
4. Supply Chain Analyst
5. Operations Manager
6. Logistics Coordinator
7. Sustainability/Compliance Officer

2. How many years of experience do you have in the fashion supply chain industry?

1. Less than 1 year
2. 1–3 years
3. 4–6 years
4. 7–10 years
5. More than 10 years

3. Which department are you currently working in?

1. Sourcing
2. Planning
3. IT / Systems
4. Logistics / Distribution
5. Procurement
6. Sustainability / CSR
7. Other (please specify)

4. What is the size of the fashion company you work for?

1. Fewer than 50 employees
2. 51–200 employees
3. 201–500 employees
4. 501–1,000 employees
5. More than 1,000 employees

5. Which region does your company primarily operate in?

1. North America
2. Europe
3. Asia
4. Middle East
5. South America
6. Africa
7. Global / Multinational

6. Do you know what blockchain is?

1. Yes
2. No
3. Maybe

7. Do you currently use blockchain in your work?

1. Yes
2. No

Section 2: Blockchain Traceability Capability

Blockchain is a distributed digital ledger technology that allows data to be recorded in a secure, transparent, and immutable manner. In supply chain management, it enables stakeholders to track the movement of goods, verify transactions, and enhance traceability across multiple stages of production and distribution. The following section explores how blockchain impacts traceability in the fashion supply chain.

No.	Statement	1	2	3	4	5
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Blockchain enhances the traceability of raw materials in the fashion supply chain.					
2	Real-time data tracking through blockchain improves sourcing transparency.					
3	Blockchain helps detect irregularities or unauthorized changes in supply chain processes.					
4	Product movement from origin to store is more transparent due to blockchain.					
5	Traceability enabled by blockchain fosters ethical sourcing.					

Section 3: Blockchain Data Immutability

No.	Statement	1	2	3	4	5
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

1	Blockchain ensures that supply chain data cannot be tampered with.					
2	Immutable records help hold suppliers accountable for their practices.					
3	Historical supply chain data stored on blockchain improves audit accuracy.					
4	Blockchain reduces the risk of fraud in the fashion supply chain.					
5	Permanent records on blockchain enhance trust among supply chain partners.					

Section 4: Smart Contract Automation

No.	Statement	1	2	3	4	5
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Smart contracts automate compliance with sustainability standards.					
2	Blockchain-based automation reduces manual errors in supply chain operations.					
3	Automated contracts ensure timely payments to suppliers.					
4	Smart contracts support faster and verifiable regulatory checks.					
5	Using smart contracts minimizes delays in decision-making processes.					

Section 5: Stakeholder Data Accessibility

No.	Statement	1	2	3	4	5
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Blockchain allows all stakeholders to access real-time supply chain data.					
2	Increased data visibility improves collaboration among supply chain actors.					
3	Accessible blockchain data supports sustainability assessments.					
4	Stakeholder access to blockchain reduces data asymmetry.					
5	Data accessibility via blockchain enhances supply chain accountability.					

Section 6: Supply Chain Transparency

No.	Statement	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1	Blockchain improves overall transparency across the supply chain.					
2	Transparent supply chains help identify unethical sourcing practices.					
3	Blockchain enhances information sharing among fashion industry stakeholders.					
4	Supply chain transparency contributes to achieving SDG 12 goals.					
5	Blockchain supports ESG reporting through improved data availability.					

APPENDIX B: INTERVIEW QUESTIONS

Blockchain

- How do you perceive the role of blockchain in improving supply chain transparency?
- What challenges do you foresee in implementing blockchain within your current operations?

Supply Chain

- What are the biggest visibility gaps in your supply chain today?
- How does data accuracy affect your day-to-day supply chain decisions?

Sustainability

- How important is traceability for meeting your company's sustainability goals?
- What sustainability standards or frameworks guide your sourcing practices?

Fashion

- How has digital innovation shaped the supply chain dynamics in the fashion sector?
- What are the main ethical concerns facing the fashion supply chain today?