An exploratory study of blockchain technology implementation to address traceability challenges in the luxury apparel industry

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AUTHOR'S DECLARATION

I declare that the work in this dissertation was carried out in accordance with the Regulations of the University of Bristol. The work is original except where indicated by special reference in the text and no part of the dissertation has been submitted for any other degree.

Any views expressed in the dissertation are those of the author and in no way represent those of the University of Bristol.

The dissertation has not been presented to any other University for examination either in the United Kingdom or overseas.

SIGNED: ……

DATE: 14/05/2024

Abstract

The luxury apparel industry faces several challenges that undermine the effectiveness of companies operating in the sector, resulting in social and environmental scandals, a loss of consumer trust, and reduced revenue (Zheng et al., 2012; Anita et al., 2004; Trieblmayer, 2018). Issues such as the proliferation of counterfeit goods, unauthorised distribution, and the lack of supply chain visibility necessitate an improvement of supply chain traceability. Blockchain technology has emerged as a possible solution to these issues, and so an exploratory study to investigate the implications a blockchain traceability system has been conducted. A comparative study using Walmart as an example of successful blockchain implementation has been explored, in order to analyse the potential benefits and challenges of adoption in the luxury apparel industry. The findings of this study demonstrate that blockchain technology has significant promise for improving supply chain traceability through its inherent properties. However, several challenges of adoption are identified, consisting of industry resistance to technology adoption and the need for demonstratable financial benefits. Despite these barriers, the study concludes that blockchain can provide a significant improvement in addressing traceability challenges in the luxury apparel sector.

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1.0: Introduction

The luxury apparel industry has long grappled with challenges of traceability, authenticity, and sustainability due its complex, highly globalised supply chains and labour-intensive production (MacCarthy et al., 2013). As consumers become more aware and concerned about issues of environmental and social sustainability (De Brito et al., 2008), the lack of supply chain traceability presents a significant barrier to negate these concerns (Badzar, 2016). Corporations in the luxury apparel industry often have little knowledge of the origin of materials for the goods they produce or sell (Abeyratne & Manfared, 2016), and so researchers and practitioners are searching for solutions to improve supply chain transparency, visibility, and traceability (Sodhi & Tang, 2019).

In response to these challenges, blockchain technology has become an emerging solution, offering capabilities to enhance traceability, transparency, and accountability within supply chains (Tieman & Darrun, 2017). Whilst initially created as to serve as the foundational structure of cryptocurrencies, blockchain technology has since evolved into a transformative tool across various sectors due to its decentralised, immutable, and transparent nature. In the context of the luxury apparel industry, blockchain has the potential to revolutionise supply chain management by enabling the secure tracking of products, addressing concerns of transparency and traceability (Agrawal, 2021). However, limited empirical study has been undertaken in diverse industry contexts, such as the luxury apparel industry (Kamath, 2018). Furthermore, existing studies have focused on the technical aspects of blockchain implementation, neglecting the managerial and strategic factors that are essential to widespread adoption (Feline & Lakhani, 2018). Therefore, this dissertation aims to fill a gap in the literature by conducting an exploratory study to better understand practical implications and challenges of a blockchain traceability system. The adoption of a managerial approach allows a holistic understanding of how blockchain technology can enhance traceability and supply chain performance (Querioz et al., 2019).

This dissertation explores the implementation of a blockchain traceability system to address traceability challenges in the luxury apparel industry. Through a comprehensive analysis of a successful blockchain application in the agri-food industry, insights are gained into the potential benefits and challenges of adoption into the luxury apparel sector. It is found that challenges that have long plagued the luxury apparel industry, such as counterfeiting and unauthorised distribution, are able to be reduced by the implementation of a blockchain traceability system. In addition, supply chain transparency, visibility and accountability are able to be significantly increased through blockchain implementation. This research contributes to the growing body of knowledge on blockchain technology implementation in supply chain management (SCM) literature. Furthermore, valuable insights for stakeholders and managers in the luxury apparel industry are gained, as practical implications are addressed. Lastly, key factors that influence blockchain adoption are discussed, such as industry culture, collaboration, and technological understanding, in order to provide the full context of the challenges in implementing a new technology.

2.0: Literature Review

The textile/apparel supply chain is notable for its tendency of human rights violation scandals (De Brito et al. 2008; Seuring and Müller 2008). The complexity and opaque nature of textile supply chains prevents the stable development of ethical practices at each stage of the value chain (Shaw and Duff, 2002). The sourcing of materials, often from multiple third-party suppliers, adds an additional layer of complexity to the production process (Lamming et al., 2000). This dispersed and multi-tiered sourcing model means it is difficult to maintain oversight and enforce compliance with ethical practices throughout the supply chain. The structure of the industry is divided into four main stages – fibre and yarn production, fabric production, garment manufacture, and retailing (Ma et al., 2016). The geographical variation of these stages complicate the issues of traceability and transparency. Each stage not only increases the distance between

the origin of raw materials and the end consumer, but also multiplies the opportunities for ethical issues in labour practices and environmental damage. Corporations in the luxury apparel industry face various challenges that will be addressed in this literature review, with the intention to explore the implications of a solution utilising blockchain technology.

2.1: Counterfeit goods

The counterfeiting of products in the luxury apparel industry has emerged as a vital challenge to corporations, which can result in severe implications for brand integrity and consumer trust. Boissieu et al. (2021) define counterfeiting as the substitution of high-value goods with low quality imitations, which are packaged in authentic, reused, or imitated containers. This can lead to diminished brand value, consumer confidence, and the infringement of intellectual property rights and trademarks, affecting market valuation and customer loyalty (Soon & Manning, 2019). The global trade in counterfeit products is highly lucrative – estimated at approximately 4.5 trillion US dollars, the luxury apparel sector accounting for around 60-70% of this market (Harvard Business Review, 2019; Zheng et al, 2012). This highlights the urgency in which this issue must be addressed. Grossman & Shapiro (1998) further categorise counterfeits into non-deceptive and deceptive products. Non-deceptive counterfeits are those that the consumer recognise as fake when purchased and are often of a low quality and sold at a low price. In contrast, a deceptive counterfeit are sophisticated imitations that are sold as genuine products. Whilst non-deceptive counterfeits are an issue due to the infringement of intellectual property, consumers are aware of their inauthenticity, and so this is seen as having less effect on the reputation and value of the brand. Therefore, deceptive counterfeits will solely be considered when addressing the issue of counterfeit goods.

2.2: The grey market

The grey market in the luxury apparel industry presents a complex legal challenge, as well as a potential issue of brand integrity. The grey market is defined by Li et al. (2016) as the unauthorised distribution channels through which branded products are sold without the consent of the owners of the intellectual property. Unlike the black market, which clearly break the law though the selling of counterfeit or stolen goods, the legality of the grey market is often protected, as rulings by high courts in Europe and America have upheld these activities as beneficial to consumers (Autrey et al., 2014). Despite this legal backing, the impact of the grey market on luxury brands is negative. Grey market activities can significantly erode a brand's image by selling products to consumer segments that the brand deliberately avoids (Anita et al., 2004). This can dilute the brand's image of exclusivity and prestige, which are critical to the identity of many luxury brands.

2.3: Supply chain visibility

Efficient supply chain management relies on the availability and utilisation of vast quantities of data in order for managers to make informed decisions (Williams et al., 2013). However, conventional supply chain structures are marred by information asymmetry due to the centralisation of data, depriving various stakeholders comprehensive access (Treiblmaier, 2018). In order to address this, a collaborative solution spanning the entirety of the supply chain is needed, aiming towards complete visibility – described "the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events (Francis, 2008). Supply chain managers recognise supply chain visibility as a catalyst for inter-company collaboration, which can foster trust and enhance efficiency (Francis, 2008; Johnson et al., 2013; Bartlett et al., 2007). Multiple factors of successful supply chain management, such as cost control, inventory management, and

logistical operations, rely heavily on visibility (Kwon & Kim, 2018). Effectively leveraging and distribution of information among suppliers can have various positive impacts, such as improved supply chain responsiveness, enhanced measurement capabilities, and the optimisation of key performance metics, ultimately leading to heightened productivity, superior customer service, and enhanced firm performance (Kim et al., 2006; Acquaye et al., 2014; Caridi et al., 2013; Frohlich and Westbrook, 2001).

Therefore, the issue with these of improving these issues is that companies, NGOs, and stakeholders do not have the required information about the supply chain to monitor these factors properly. Due to the complex structure of the textile/apparel supply chain, further complicated by the large geographical spread of facilities, the focal firms often face issues in monitoring the supply chain's sustainability risk (Agrawal, 2019). Information asymmetry and low visibility are major challenges in the sector, that have contributed to major scandals and catastrophic events. A consistent way of gaining information on each stage of the supply chain is needed in order to measure the performance indicators of these issues previously mentioned. Consequently, the need to develop a system to improve traceability across the supply chain is proposed, using the innovations of emerging technologies.

2.4: Traceability

Traceability, as defined by ISO (2015) as: "the ability to trace the history, application or location of an object", encompasses not only the tracing of materials and parts, but also includes the maintenance and documentation of the distribution of the product and its application, making it essential for supply chain visibility.

Granularity is an important consideration in a traceability system. According to Karlsen et al. (2012), the level of granularity, or size of a traceable unit within the system, can vary significantly and is determined by the specific needs of the traceability system. Whilst an increased granularity can yield an increase in usable data, this also increases the costs and complexity of system, which can present significant challenges in terms of the practical implementation of traceability solutions. This vertical dimension of traceability therefore requires appropriate strategic planning to balance detail with cost and complexity.

Of equal importance, the horizontal dimension of traceability focuses on the start and endpoints of the traceability system within the supply chain. This dimension can vary from full horizontal traceability – able to track the product from the origin of raw materials to the end consumer – to a limited scope depending on the specific aims of the traceability system. The decision upon the extent of horizontal traceability hence significantly impacts the overall efficacy and resource allocation of the system.

Furthermore, maintaining the traceability of the product involves various key requirements, as specified by ISO (2015). The identity and status of the product must be established and adequately maintained, in addition to keeping a record of all serial and/or batch numbers. The concept of a 'digital twin', as highlighted by Srai et al. (2019), illustrates a sophisticated approach in where each physical asset has an attached virtual counterpart, which can ensure detailed and credible tracking. This can be pivotal for enhancing the reliability of the traceability system, offering increased granularity and real-time monitoring capability, thus enhancing the overall integrity of the luxury apparel supply chain.

2.5: Blockchain technology

Blockchain was created to serve as the mechanism on which the first peer-to-peer digital currency in the world, Bitcoin, authorises payments (Nakamoto, 2011). It is a digital, decentralised, and distributed ledger that enables peer-to-peer transactions using cryptographic algorithms and consensus mechanisms, linked together in a chain of 'blocks'. The core characteristics of blockchain are transparency, programmability, immutability, decentralisation, consensus, and distributed trust (Treiblmaier, 2020). The transparency of blockchain manifests in granting all users read-only access to previous transactions, whilst the immutability aspect means all entries are unable to be changed. These features are both highly desirable in systems of traceability (Xiwiei et al., 2019). The decentralised nature of blockchain enables the distribution of trust such that it does demand confidence in any single authority (Treiblmaier, 2020). This eliminates the need for an involvement of any third party for the management of transactions, resolving issues of trust and improving the process of transactions (Wang et al., 2019). However, the effective implementation of blockchain has several challenges. Firstly, concerns about the privacy of data stored on blockchains have been raised (Ren et al., 2020). There are concerns regarding the high cost of the implementation of a blockchain system (Kamble et al., 2019). It can therefore be considered a risky investment on behalf of companies; however, the potential remains in the technology to solve important issues in the pursuit of sustainability.

4 properties of blockchain have been identified that make the technology attractive to address key problems in contemporary supply chains:

Transparency:

The decentralised nature of the blockchain network enables all participants to be given access to the exact copy of the distributed ledger at any time in the form of a public blockchain (Maull et al., 2017). A private blockchain on the other hand, allows varying levels of information access depending on the participant. This means that regulatory bodies can have access to information that can be

considered too sensitive to be public, in order to ensure that adequate privacy is also implemented.

Security:

All blocks in the ledger and timestamped and identified using cryptographic keys. Once a block has been added, the immutability of blockchain ensures data can only be added, not deleted or edited (Maull et al., 2017). This ensures that data is not manipulated after it has been released and prevents censorship. All transactions stored on the blockchain are confirmed by a consensus mechanism, which removes the reliance of trust seen in traditional systems.

Autonomous Smart Contracts:

Smart contracts are computerised transaction protocols that execute the terms of a contract. This allows a blockchain platform to perform automatic execution of transactions once triggered by other transactions (Xiwei et al., 2019). This means that when a blockchain is started, rules can be created which regulate the chain without the need of an intermediary.

Traceability:

The chronological record of blockchain transactions is the key principle of blockchain traceability. Each block is linked cryptographically to the one preceding it, creating an immutable historical record of transactions (Viriyasitavat and Hoonsopon, 2019).
This ensures the validity of the ledger by keeping track of changes, allowing faults to be identified, and attempts at tampering to be highlighted.

2.6: Blockchain implementations

Despite the many potential applications of blockchain technology, it has only recently been considered in operations and supply chain management literature (Cole et al., 2019). Further still, only limited studies have been conducted into

blockchain's potential implementations specific to textile/apparel supply chains (Hader et al., 2022), due to the emerging nature of the technology. Most of the papers in the literature focus on theoretical frameworks of blockchain's application in the textile/apparel supply chain (Agrawal, 2019), however, practical applications have been explored. Kumar et al., (2018) suggested that blockchain could provide a trustworthy information resource in textile supply chain management, with the benefit of improving traceability and information sharing identified by numerous scholars (Tieman and Darun, 2017; Badzar, 2016). Fu et al. (2018) presents a framework for emission trading in the textile/apparel manufacturing industry using blockchain, arguing that it's use in ETS schemes is plausible and desirable. However, due the lack of real-world implementation of blockchains use in ETS, this application will not be explored further in this study. Some studies note that blockchain can address issues of asymmetric information, integration, and trust problems to enhance supply chain management (Badzar, 2016; Hader et al., 2022; Agrawal, 2021).

The table in Figure 1 (below) explores some of the potential applications of blockchain's 4 properties identified in the previous section.

Blockchain Property	*Potential Application*
Transparency	- Traceability information for customers and stakeholders to assess sustainability record of retailer/designer (Xivei et al., 2019) - Reputation-based trading system, encouraging participants to adopt a long-term solution in emission abatement (Khaqqi et al., 2018)

Security	- Secure storage of sensitive data on the blockchain (Maull et al., 2017)
Autonomous Smart Contracts	- Smart contract that can ensure provenance of raw materials (Agrawal, 2021).
Traceability	- Traceability system for information sharing between supply-chain partners (Azzi et al., 2019)

Figure 1. Blockchain properties and potential applications

2.7: Blockchain traceability solution

Adoption of a blockchain-based traceability system is one of the possible solutions to address social and environmental sustainability challenges, with the intention of ensuring seamless information sharing among supply chain partners. This system aims to record and track all information related to each stage of the value chain whilst safeguarding sensitive data (Azzi et al., 2019). This technology is relevant to changing market conditions due to the increased scrutiny companies face from customers in the form of sustainability assurance. Blockchain can assist in tracking the trail of the product (Zhao et al., 2019; Appelbaum, 2005), allowing customers to not only assess the sustainability record of the company responsible for the end-product, but also the companies responsible for production and the extraction raw materials.

2.8: Barriers to adoption

The adoption of blockchain as a traceability system within supply chain management (SCM) encounters several significant barriers, predominantly at the level of organisation leadership and resource allocation. Research by Kumar et al. (2017) has indicated that, similar to the integration of the internet into SCM, the adoption of blockchain technology is hindered by various interrelated concerns: insufficient support from senior management, budgetary constraints, and a lack of competitive pressure. To further emphasise the critical role of senior leadership acceptance, Asare et al (2016) argue that the absence of executive support can decisively halt the adoption of innovative technologies, such as blockchain. This lack of support is compounded by a knowledge gap at the executive level, as noted by Van Hoek (2019), who identifies that many executives have a poor understanding of the costs and benefits associated with blockchain technology. An additional barrier to the implementation of a blockchain system of traceability in the textile/apparel industry is the acceptance of the new technology by consumers. The Technology Acceptance Model (TAM), proposed by Davis (1989), has been effectively used in scholarly literature to examine the understanding and competency of users when adopting a new technological service. A number of case studies have already been conducted to consider the user acceptance of a blockchain-based system, despite its recent development (Shin, 2019; Shrestha & Vasssileva, 2019). However, these studies are limited to application for blockchain as a financial technology (Folkinshteyn & Lennon, 2016), and so the findings may not be relevant to the luxury goods sector. Regardless, previous studies imply that a blockchain-based system will be accepted by consumers and corporations “if it perceived as trustworthy, convenient and useful” (Shin, 2019).

2.9: Pilot traceability systems in luxury goods sector

Some corporations in the luxury goods sector have already piloted the implementation of a blockchain traceability system (LVMH, 2021; Consensus, 2021; Lenzing AG, 2020). The AURA Consortium, consisting of luxury goods conglomerate LVMH and its partnership with blockchain technology firm ConsenSys and Microsoft Azure, aim to lead and call for industry wide collaboration with an effort to examine and deploy blockchain technology to improve product traceability and authenticity (LVMH, 2021; ConsenSys, 2021).

By tracking the origin of products from the origin of the raw materials to the point of sale, the consortium aims to provide consumers and stakeholders with traceability information that ensures the authenticity of luxury products. Whilst this is a promising step towards the widespread acceptance of blockchain technology application to solve traceability, the consortium has not provided information on the results of this pilot test, or whether it was effective in achieving its aims. Lenzing AG, a prominent Austrian textile manufacturer, has also trialled a blockchain solution to enhance the authenticity and sustainability of their fibre products (Lenzing AG, 2020). Recognising the challenges posed by counterfeiting and the need for sustainable practices in production, Lenzing AG have adopted blockchain technology to ensure their sustainable fibres are used responsibly throughout the supply chain, in addition to verifying their authenticity. Similarly, no information upon the implications of this test could be found.

To conclude, whilst blockchain solutions have been trialled in the luxury apparel supply chain, data on implications of the technology are lacking. It is therefore difficult to draw empirical conclusions upon the effect of blockchain technology on traceability factors. Therefore, in order to effectively analyse what the potential benefits of utilising a blockchain traceability system might be in the luxury goods sector, a case study of effective blockchain technology implementation in a different industry must be identified.

2.10: Implementation of blockchain in the agri-food industry

Walmart's partnership with IBM has yielded a blockchain technology system that enhances traceability across its supply chain in order to solve long standing issues of food contamination and food waste. The system can efficiently capture and control detailed records, including audits and safety protocols, securely as electronic certificates. It also can provide complete end-to-end visibility, detailing information such as farm origins and environmental conditions. This enhanced level of traceability has demonstrated blockchain's suitability for the system, as it allows Walmart to quickly pinpoint issues, improve food safety,

reduce recall costs, and enhance operational efficiency significantly (Del Castillo, 2016). In order to assess the implications of LVMH's blockchain traceability system pilots, this case study will be used to analyse the potential benefits and improvements blockchain technology might have upon traceability in the luxury apparel supply chain, in order to address issues mentioned in this literature review.

The following research question is proposed:

How effective and viable is the implementation of blockchain technology as a traceability system in companies operating in the luxury goods supply chain, in order to address issues of visibility and authenticity?

Aim: To explore the implications of implementing a blockchain traceability system in the luxury apparel supply chain

Objectives:

1- Identify traceability issues and performance indicators in the supply chain
2- Investigate how the properties of blockchain technology are effective in solving traceability challenges
3- Analyse implications of blockchain technology implementation upon traceability performance

3.0: Methodology

3.1: Philosophical position

This research utilises the philosophical position of 'pragmatism', whereby concepts are only relevant when they support action (Keleman and Rumens, 2008). Regarding ontology, which can be define as assumptions about the realities encountered in research (Thornhill et al., 2016), pragmatism refuses involvement in metaphysical concepts such as truth and reality. In lieu of this, it accepts that there can be multiple or singular realities that are open to empirical inquiry (Creswell & Clark, 2011). In relation to the two philosophical stances positioned at opposite ends of the ontological spectrum - objectivism and subjectivism – pragmatism aims to reconcile or reject these stances. Pragmatist scholars have held the opinion that an objective reality exists separate from human experience, however, this reality is grounded in the environment and can only be encountered through human experience (Goals & Horsheim, 2000; Tashakori & Teddlie, 2008). Logically succeeding ontology is the discussion of epistemology, defined as assumptions regarding human knowledge (Thornhill et al., 2016). Pragmatism rejects the traditional philosophical dualism of positivism and constructivism, aiming to allow the researcher to abandon the perception of a 'forced dichotomy' (Creswell & Clark, 2011). It considers theories, concepts, ideas, hypothesis and research findings not existing in an abstract form, but only in terms of the roles they can play as instruments of thought and action, in terms of their practical consequences in specific contexts (Keleman & Rumens, 2008). In the context of this study, a pragmatic approach was selected as it supports the use of mixed methods to draw comprehensive insights across different industries – luxury apparel and food – which highlights the flexibility in selecting methods that best achieve the research objectives. The philosophy emphasises the importance of practical outcomes and real-world applications, guiding the selection of case studies and methodologies that are grounded in their utility and relevance to stakeholders. This approach therefore promotes an understanding that is both dependant on context and tailored to specific practical implications.

3.2: Research design

This research employs a comparative case study methodology, a strategy that is seen as effective in understanding the implications and outcomes of implementing innovative technologies across different sectors. This approach allows for an in-depth analysis of each case within its real-life context, providing a robust framework for identifying points of similarity and disparity in the application of blockchain technology. An abductive approach will be used in this study, leveraging empirical data to explore the use of blockchain technology in the luxury goods industry. This approach is useful for this research through its capacity to bridge existing research gaps by integrating and adapting insights from other industries, allowing the creation of a preliminary conceptual framework which is used as the foundation for exploratory analysis. As the primary aim of this research is to analyse the implications of blockchain traceability systems in the luxury apparel industry, documented results from similar applications in the food industry will be used as the basis of successful implementation, as it has seen marked successes in enhancing traceability and transparency. The comparative case study approach was selected for its strength in facilitating an understanding of complex issues and allowing an exploration of a similar application within a varied context. The research is structured with the intent to provide an in-depth analysis into each industry's unique challenges and opportunities concerning blockchain adoption. The use of an exploratory study design is particularly relevant for this research, due to the nascent application of blockchain technology within the luxury goods sector and the limited empirical data in regard to its outcomes.

Data will be collected by reviewing journal articles, scholarly monographs, industry reports, and case studies relevant to blockchain implementations in both the luxury apparel and food industries. This allows the research to consider all

information that is readily available, allowing a large pool of data. However, it is necessary to ensure the credibility of this data, and that it is up to date with recent developments in blockchain technology. The success of this research is dependent on the quality of the original sources of data, and so it is important that the selection and use of data is systemic and fair.

The cases have been chosen to ensure that they are information rich and exemplify a typical large corporation in their respective industry. The selection of Walmart to represent the agri-food industry can be justified by several factors – Firstly, Walmart is recognised globally as the largest food retailer, with over $500 billion in annual revenue, meaning it has substantial market leadership and influence (Yoffie & Fisher, 2019). Additionally, Walmart has conducted two successful blockchain pilots in tracking the production of mango and pork, demonstrating a significant advancement in supply chain management (Kamal, 2018). Lastly, there is a wealth of data regarding Walmart's blockchain implementation (Del Castillo, 2016; Kamath, 2018; Blanchfield & Welt, 2012; Kaye, 2016), providing a suitable foundation for analysis. In order to provide accurate implications of blockchain's use in the luxury apparel sector, a company of similar size and capability as Walmart was selected. LVMH is the global industry leader in luxury apparel (Cavender & Kincade, 2014), controlling 75 luxury brands and holding a 18% market share of the global personal luxury goods market (Statisa, 2020). In addition, the company claims to be known for its innovation and uncompromising quality (LVMH, 2012), signifying a willingness to adopt emerging innovative technologies. A key business practice of LVMH is the implementation of changes that address the challenges of the modern industry environment (Park & Kincade, 2011), further justifying the rationale of its selection.

3.3 Limitations

The methodology used in this dissertation, whilst able to produce valuable insights into blockchain technology application, has certain limitations that must

be considered. Firstly, this analysis does not address the technical barriers associated with the adoption of blockchain, such as the design of the traceability system or its operational efficiency. In addition, the generalisability of the findings is constrained by the variability of the luxury goods industry. Factors such as the size of the organisation, organisational culture, and geographic location can significantly influence the adoption of blockchain technology. Therefore, the conclusions drawn in this study are dependent on context and may not represent the broader industry. The reliance on secondary data sources and the interpretive nature of the analysis can introduce subjectivity and bias, particularly in terms of ambitious or contradictory data. This subjectivity can skew interpretation and impact the findings of the research. The absence of primary empirical data may impede the ability to capture real time innovations in the industry, instead relying on documented outcomes that may not encapsulate the evolving landscape of blockchain technology implementation.

3.4: Ethical Considerations

Ethics in research can be defined as: "the standards of behaviour that guide your conduct in relation to the rights of those who become the subject of your work, or are affected by it" (Saunders, Lewis and Thornhill 2015, p239). As this research relies on the use of secondary data for analysis, issues such as transparency and informed consent of the research objectives for participants, as well as protections of data privacy and security, are not relevant. However, this research will have to consider the effects this research might have on local communities within the textile supply chain. This can include how the adoption of blockchain may affect the socio-economic dynamics, employment, and cultural practices in regions where the textile supply chain is concentrated and taking steps to mitigate any unforeseen negative consequences.

4.0: Findings

4.1: Agri-food supply chain case study

Objective 1: Identify issues of traceability

Contamination and mismanagement of food is a large and well-documented issue in the agri-food supply chain – a report by the World Health Organisation (WHO) has estimated that around one in ten people suffer from food poisoning and related illnesses worldwide, causing 420,000 deaths every year (WHO, 2017). The 2006 E. coli outbreak in the US, caused by a single contaminated batch of spinach, demanded heavy resources upon all companies involved in the supply chain. It took two weeks for health officials to trace the origin of contamination: a single day's production of one supplier (Produce Processing, 2007). The supply chain's slow response in tracking the source of the contamination resulted in significant erosion of customer trust, as well as inflicting prolonged economic harm to spinach farmers (Kamath, 2018).

In 2011, a substantial mislabeling of pork created a national scandal in China (Bradsher, 2011). A breach in the supply chain of contaminants such as melamine, Sanlu toxic milk powder, trench oil and clenbuterol further eroded consumer trust in Chinese food markets (Hatton, 2015). China possesses a vastly outdated agricultural logistics system – up to 25-30% of food is wasted annually (Liu, 2013). The Chinese government body of The Office of Economic Co-operation and Development identified several issues the domestic food industry faces: deficient information at each stage of the supply chain, waste in the restaurant and catering sector, and a lack of regulatory co-ordination (Liu, 2013).

Extrapolating from these examples, numerous traceability issues can be identified. Firstly, there is a deficiency in information at each stage of the supply chain to accurately trace the sources of contamination. Secondly, improved speed

in tracing the origin of contaminated goods is required in order to decrease the risks associated with food contamination and maintain consumer trust. Thirdly, a reduction in food waste and spoilage is needed in order to increase the efficiency of agricultural logistics systems. Lastly, supply chain visibility and transparency are needed to ensure all parties have access to relevant information, allowing supply chain managers to make informed decisions and increasing the accountability of supply chain participants.

Supply chain issue	*Example*
Reducing the time for tracking origin of products	It took two weeks to trace the origin of contamination (Produce Processing, 2017). Slow response in tracking contaminated products resulted in erosion of customer trust and significant economic damage (Kamath, 2018)
Identifying the source of food contamination	Food poisoning causes 420,000 deaths per year (WHO, 2017) Contaminants in the supply chain drastically eroded consumer trust in Chinese food markets (Hatton, 2015)
Reducing food wastage and spoilage	Up to 25-30% of food is wasted in China's agricultural system (Liu, 2013)
Increasing Supply chain visibility, transparency, and accountability	Chinese governmental body claims deficient supply chain information as a key issue of the agri-food industry (Liu, 2013)

Figure 2. Own work

Objective 2: Link issues with blockchain functions

(1): Reducing the time for tracking origins of products

The properties of blockchain are well suited to reducing the time required to track the origins of products in the agri-food supply chain. In particular, the property of transparency can ensure that all transactions and their associated information are visible and accessible to all participants in the supply chain (Xiwei et al., 2019). This universal visibility means that the information required to track products are readily available and verifiable in real time. In addition, the property of traceability in blockchain is powered by the technology's ability to create a continuous and unalterable record of each transaction (Tieman & Darun, 2017). Each transaction is also linked to the previous and subsequent transactions, meaning that an attempt to trace the origins a product can be done swiftly and accurately, as each step in the product's journey is recorded sequentially. Consequently, blockchain can drastically reduce the time taken for tracing products, through immediate and reliable accessibility.

(2): Identifying the source of food contamination

The blockchain properties of immutability and traceability can have a transformative effect in identifying the source of food contamination within supply chains. Immutability ensures that once data is recorded on the blockchain, it cannot be altered or tampered thereafter (Hader et al., 2022). This permanence is vital when the integrity and accuracy of historical data is important, as is the cause when identifying food contamination sources. When an incident is detected, stakeholders can trust the unchangeable record of transactions to accurately identify product journey details without the risk of falsification or data corruption. Traceability in this case, through the creation of a comprehensive, end-to-end trail (Xiwei et al., 2019), makes it possible to pinpoint the exact stage at which contamination may have occurred. This provides an accurate, efficient method to identify contaminated products and take appropriate action.

(3): Reducing food wastage and spoilage

The integration of blockchain technology, through the use of its properties of transparency, traceability, and the application of autonomous smart contracts, can present a potent solution for reducing food wastage and spoilage within supply chains. The transparency of blockchain can provide real-time access to critical data points such as the handling, storage, and transportation conditions of perishable goods, allowing managers to make immediate and informed decision making (Williams et al., 2013), in addition to promoting accountability across all stages of the supply chain (Bartlett et al., 2007). This can be further enhanced through the deployment of autonomous smart contracts. These self-executing contracts are programmed to automatically carry out a specific action when a predefined condition is met (Viriyasitavat & Hoonsopon, 2019). In the agri-food supply chain, this can be utilised to initiate corrective measures when the conditions of perishable goods exceed safe thresholds (Gale, 2017). This instant response can significantly mitigate the risk of spoilage that may occur due to a delay in human intervention.

(4): Increasing supply chain visibility, transparency, and accountability

The blockchain properties of transparency and immutability can be instrumental in enhancing visibility, transparency, and accountability, which are key aspects of a sustainable, fair, and efficient supply chain. Transparency, when facilitated by blockchain technology, ensures all information concerning supply chain transactions are openly available and accessible to authorised stakeholders (Xiwei et al., 2019). This can include data on product origin, handling, processing, and delivery timelines. Such widespread accessibility can promote an environment of accountability, through a high degree of operational visibility (Batubara et al.,

2019). Immutability secures this transparent data from unauthorised alterations or deletion. This aspect is vital in contexts where the integrity of the supply chain is of paramount importance, to ensure regulatory compliance and high ethical standards. Parties are more likely to adhere to agreed standards and regulations when they know their actions are being recorded in an unchangeable format that is visible to all other participants (Batubara et al., 2019), leading to heightened accountability.

Supply chain issue	*Blockchain property*	*Blockchain traceability system features*
Reducing the time for tracking origin of products	- Transparency - Traceability	All transactions and their associated information are visible and accessible to all participants in the supply chain (Xiwei et al., 2019). Continuous and unalterable record of each transaction provides fast and accurate tracking of products (Tieman & Darun, 2017).
Identifying the source of food contamination	- Traceability - Immutability	Data cannot be altered or tampered with, ensuring integrity of information (Hader et al., 2022). End-to-end trail makes it possible to pinpoint the exact stage at which contamination may have occurred (Xiwei et al., 2019).
Reducing food wastage and spoilage	- Traceability - Autonomous smart contracts	Real-time access to critical data points such as the handling, storage, and transportation conditions of perishable goods Automatic initiation of corrective measures when the

	-	Transparency	conditions of perishable goods exceed safe thresholds (Gale, 2017)
Increasing Supply chain visibility, transparency, and accountability	-	Transparency	Widespread accessibility can promote an environment of accountability (Batubara et al., 2019)
	-	Immutability	

Figure 3. Own work

Objective 3: Analysis of case study

Walmart has worked in partnership with IBM to develop and implement food provenance pilots that utilise blockchain technology (Tiwari, 2016). The blockchain traceability system IBM has produced is based on Hyperledger Fabric, an open-source framework which supports modular architecture and components such as consensus and membership services (IBM, 2017). The results of their blockchain pilots are analysed as follows:

(1): Reducing the time for tracking the origin of products

From the case study of Walmart's application of blockchain, it is stated that time taken to track mangoes from their origin had been reduced from 7 days to 2.2 seconds (Kamath, 2018), resulting in a vastly significant 274,909x decrease in tracking time. Whilst this only applies to one product in the supply chain of Walmart, this has wide implications for the significant reduction of tracking times through the implementation of a blockchain traceability system. In addition, it is stated in that Walmart's blockchain pilot has had a marked improvement in the speed and accuracy of providing relevant information across all stages of the supply chain (Blanchfield & Welt, 2012). This is significant as it

demonstrates blockchain's ability to efficiently provide a solution to this long-standing supply chain issue.

(2): Identifying the source of food contamination

The IAEA (2011) claim that traceability is an essential factor in the prevention or fast response to food contamination or bioterrorism incidents. With the application of blockchain, Walmart has the ability to remotely trace any information required to prevent or respond to outbreaks (Kaye, 2016), in addition to the previously mentioned speed and accuracy of tracking (Kamath, 2018; Blanchfield & Welt, 2012). These two factors combined result in a dramatic increase in capability to deal with food contamination outbreaks, negating effects of diminished consumer trust.

(3): Reducing food waste and spoilage

The capability of Walmart to prevent food waste and spoilage in its supply chain has been significantly increased due to blockchain's application. The blockchain-enabled system enhances the granularity of traceability, thereby allowing managers to make informed decisions (Bottemelier, 2011). Rather than discarding entire batches, specific products that fail to meet quality standards can be identified and removed. This dramatically reduces waste, optimising economic and environmental resources in the process. The ability to trace each product's journey and its storage conditions allows for immediate corrective action if a deviation from optimal conditions has occurred, as observed in Walmart's practice of monitoring refrigerated containers (Gale, 2017). The use of autonomous smart contracts to instantly correct unsuitable conditions further demonstrates blockchain technology's efficiency and effectiveness in reducing food waste and spoilage.

(4): Increasing supply chain visibility, transparency, and accountability

The outcomes of Walmart's blockchain implementation upon supply chain visibility, transparency and accountability demonstrate a significant enhancement of all three factors. The horizontal dimension of traceability is greatly improved by offering a full end-to-end tracing capability (McDermott, 2017). This comprehensive visibility allows all supply chain participants to access and monitor the flow of goods from origin to consumption at a level far higher than can be achieved from traditional practices (Matta, 2013), which were displayed in the example of China's agriculture industry (Liu et al., 2013). Transparency in supply chains is a key determiner of accountability, as the recording and monitoring of data allows supply chain participants to be held accountable for actions they take (Batubara et al., 2019).

Agri-food supply chain issue	*Blockchain result*
Reducing the time for tracking origin of products (Kamath, 2018)	Walmart's blockchain solution reduced time for tracking mango origins from seven days to 2.2 seconds (Kamath, 2018), a 274,909x reduction.
Identifying the source of food contamination	With blockchain, procurement managers can remotely trace all information, from expiration dates to warehouse temperatures (Kaye, 2016)
Reducing food wastage and spoilage	The system can better pinpoint which products should be discarded without jeopardising an entire product line (Bottomelier, 2011).
Increasing Supply chain visibility, transparency, and accountability	Throughout the product life cycle, supply chain participants were able to record, crosscheck, and ensure a product's authenticity and trace its movement and quality (Doyle, 2014).

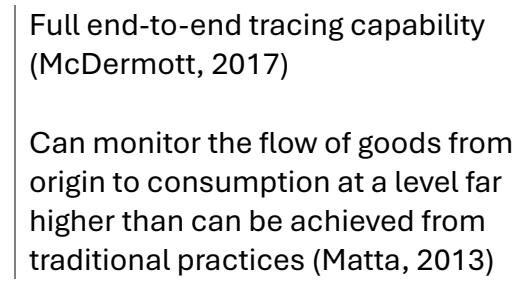


Figure 4. Own work

4.2: Luxury apparel supply chain case study

Objective 1: Identify issues of traceability

The luxury apparel industry, which distinguishes itself from the wider industry through its image of authenticity, is confronting a pervasive threat in the form of counterfeit goods. This issue is resulting in both significant losses in sales as well as the dilution of brand image, an essential element of luxury branding (Rana & Ciardulli, 2014). These challenges are further compounded in the luxury resale market, where second-hand retailers face considerable difficulties in verifying the authenticity of products, which poses a significant risk to their operational integrity (Thanasi-Boçe et al., 2022). As Castelli & Sianesi (2015) claim, the luxury apparel industry relies on its ability to protect brand value and maintain both the quality and authenticity of its products alongside efficient supply chains. Therefore, the issue of counterfeiting not only undermines these critical factors but also erodes consumer confidence in regard to the quality,

authenticity, and value of luxury apparel. Grey markets are another issue that has been identified within the literature review. This consists of unauthorised distribution channels where branded products are traded (Li et al., 2016), and has become a prominent challenge for a multitude of reasons. Brand image can be eroded by selling products to unintended consumer segments (Anita et al., 2004), in addition to grey market distributors leveraging 'free rider' gains from a brand's promotional expenditure (Ahmadi et al., 2015). Another important issue in the luxury apparel sector is the visibility, transparency, and accountability of supply chains. These three factors are seen as critical to sustainable and ethical business practices, as a lack of supply chain oversight can result in both environmental damage, and unethical labour scandals (Yang et al., 2017). Enhanced collaboration between supply chain participants has been proposed as an effective strategy to improve supply chain visibility (Caniato et al., 2011). In addition, the luxury apparel market places high emphasis on long-term supplier relationships, underpinned by a mutual level of trust, which can distinguish it from more accessible market segments. Such relationships can transform rigid quality controls into assured quality through enduring partnerships (Brun et al., 2008; Luzzini & Ronchi, 2010). Lastly, the time taken to track the origin of materials poses as another challenge the luxury apparel sector must overcome. The intricacy of luxury apparel supply chains, characterised by a multitude of intermediaries and globalised sourcing, makes the tracking of raw materials and components difficult and time consuming (Brun et al., 2008; Luzzini & Ronchi, 2010). This not only impedes efficient decision making but also undermines the ability of luxury brands in responding to emerging issues, such as ethical concerns or environmental violations. The lack of efficient traceability mechanisms often leads to prolonged periods of uncertainty regarding the origins of materials, which in turn impacts brand reputation and consumer trust (Yang et al., 2017).

To summarise, four key challenges of traceability in the luxury apparel sector are identified – the growing industry of counterfeit products, unauthorised distribution channels, supply chain visibility, transparency and accountability, and the time taken to track the origins of materials.

Supply chain issue	*Example*
Proliferation of counterfeit goods	Companies face considerable difficulties in verifying the authenticity of products, which poses a significant risk to their operational integrity (Thanasi-Boçe et al., 2022).
Unauthorised distribution (grey markets)	Brand image can be eroded by selling products to unintended consumer segments (Anita et al., 2004). Grey market distributors leverage the 'free rider' gains from a brand's promotional expenditure (Ahmadi et al., 2015)
Supply chain visibility, transparency, and accountability	Lack of supply chain oversight results in both environmental damage and unethical labour scandals (Yang et al., 2017).
Time taken to track the origin of materials	The lack of efficient traceability mechanisms impacts brand reputation and consumer trust (Yang et al., 2017).

Figure 5. Own work

Objective 2: Link issues with blockchain functions

(1) Proliferation of counterfeit goods

The blockchain properties of traceability and autonomous smart contracts can be pivotal in combating the proliferation of counterfeit goods within the luxury

apparel supply chain. The property of traceability can enable the creation of a detailed and immutable record of every transaction within the supply chain (Hader et al., 2022), from production to customer delivery. A highly granular system allows stakeholders to verify the provenance and journey of goods at any given point (Bottomelier, 2011), making it exceedingly difficult for counterfeit items to be introduced into the supply chain without detection. Autonomous smart contracts can further enhance the integrity of supply chains by automatically alerting managers when certain conditions are met (Viriyasitavat & Hoonsopon, 2019). These contracts can be designed to activate specific responses when discrepancies or anomalies indicative of counterfeit activities are detected (Bader, 2017). A smart contract can automatically halt transactions or notify stakeholders if the authentication data linked to a product does not match the secure, unalterable records on the blockchain.

(2) Unauthorised distribution

The blockchain properties of transparency and immutability can be critically effective in preventing the unauthorised distribution of products within grey markets. Transparency through the use of blockchain technology ensures that every transaction in the product journey is visible to all participants in the blockchain network. This feature can allow manufactures, distributors, and retailers to monitor the movement of goods through the supply chain in real time (Agrawal, 2019). Each participant can view, verify, and audit product origins, shipment, and distribution data, which diminishes the likelihood of unauthorised diversion and sale in grey markets.

(3) Supply chain visibility, transparency, and accountability

In the luxury apparel industry, the blockchain properties of transparency and immutability are most effective in tackling this issue. Instant access to a

decentralised and tamper-proof ledger to all relevant stakeholders can facilitate an unprecedented level of transparency, fostering an environment of trust and accountability (Batubara et al., 2019). Furthermore, the immutable nature of blockchain ensures that data is unalterable, thereby safeguarding the integrity of supply chain data.

(4) Time taken to track the origin of materials

To improve the time taken to track the origin of materials, the blockchain properties of transparency and traceability have the potential to substantially enhance the luxury apparel industry's efficiency in this regard. A rapid and accurate tracking process can be achieved through the elimination of information asymmetry and a real-time view of the product journey (Kamath, 2018). Similar to the Walmart case study, information can be visible and instantly accessible to all supply chain participants (Xiwei et al., 2019), reducing information asymmetry and tracking times throughout the supply chain.

Supply chain issue	*Blockchain property*	*Potential blockchain traceability system features*
Proliferation of counterfeit goods	- Traceability - Autonomous Smart Contracts	Allows stakeholders and consumers to verify the authenticity at any given point (Bottomelier, 2011) Automatically activates specific responses when discrepancies or anomalies indicative of counterfeit activities are detected (Bader, 2017)

Unauthorised distribution (grey markets)	- Traceability - Immutability - Autonomous Smart Contracts	Allows manufactures, distributors, and retailers to monitor the movement of goods (Agrawal, 2019).
Supply chain visibility, transparency, and accountability	- Traceability - Transparency - Immutability	Widespread accessibility can promote an environment of accountability (Batubara et al., 2019)
Time taken to track the origin of materials	- Transparency - Traceability	Provides rapid and accurate tracking process (Kamath, 2018). All transactions and their associated information are visible and accessible to all participants in the supply chain (Xiwei et al., 2019).

Figure 6. Own work

Objective 3: Analysis of case study

LVMH, through its creation of the AURA Consortium, has trialled the use of blockchain to improve product traceability and authenticity it its supply chain (LVMH, 2021). The results of this trial have not yet been published, and so potential implications of blockchain implementation are analysed:

(1) Proliferation of counterfeit goods

Blockchain technology has the potential to provide 100% accuracy in detecting counterfeit goods, assisted by the use of a 'digital twin' linked to every product (Srai et al., 2019). This means that the consumer can immediately differentiate between a counterfeit product and an authentic one, without the use of a third party. Furthermore, blockchain has the capability to authenticate the country of

origin of a product, in addition to providing proof of transactions (Casado-Vara et al., 2018). This increase in anti-counterfeiting technology can drastically reduce the proliferation of imitation products, however it is minimally effective against non-deceptive counterfeits (Bossieu et al., 2021).

(2) Unauthorised distribution

The implications of a blockchain traceability system upon the issue of unauthorised distribution are that complete downstream traceability can be achieved, in addition to the automated transfer of information from seller to buyer when the product is sold. This allows managers to analyse supply chain flows more effectively and detect any suspicious anomalies in the distribution of the product. A highly granular blockchain traceability system can greatly assist providing sufficient information to develop complex supply chain strategies that combat grey markets, which is shown to be an effective solution (Zhang & Zhang, 2015). However, managers may require a high level of technical proficiency to make full use of a blockchain traceability ledger (Maull et al., 2017).

(3) Supply chain visibility, transparency, and accountability

As demonstrated in the first case study, blockchain technology can provide end-to-end traceability that is accessible to all participants within the supply chain, thereby reducing information asymmetries that can complicate supply chain management. The risks associated with data manipulation and tampering can be significantly reduced through the application of blockchain, due to its immutable nature (Hader et al., 2022). Additionally, the tracking capabilities of blockchain can provide a robust framework for accountability, as all actions are recorded and traceable. This illustrates an effective use of blockchain technology to solve complex issues that plague traditional supply chain management and traceability

systems. Lastly, an increase in the supply of information to supply chain participants allows a further insight into demand data, increasing the ease at which lead times can be estimated (Kim & Kang, 2017).

(4) Time taken to track the origin of materials

Blockchain significantly reduces tracking times for materials – the Walmart case study resulted in a 274,909x increase, which can be replicated in the luxury apparel supply chain. This enhanced tracking capability is beneficial as it enables brands to rapidly respond to ethical issues, scandals, or any disruptions that may arise within the supply chain, minimising damage to consumer trust (Hatton, 2015). By significantly reducing the time required to trace products and materials, blockchain technology can empower supply chain managers to proactively manage their supply chain dynamics.

Supply chain issue	*Potential Blockchain result*
Proliferation of counterfeit goods	Able to authenticate a product with 100% accuracy (Srai et al., 2019) Capability for tracking, authenticating origin, and providing proof of transaction (Casado-Vera et al., 2018)
Unauthorised distribution (grey markets)	Complete upstream traceability (McDermott, 2017) Able to develop more comprehensive supply chain strategies due to increase in data (Zhang & Zhang, 2015)
Supply chain visibility, transparency, and accountability	Complete end-to-end traceability (McDermott, 2017)

	Provides suppliers with a better insight into demand data, allowing improved estimations of lead times (Kim and Kang, 2017) Prevents instances of information tampering and alteration (Hader et al., 2022)
Time taken to track the origin of materials	Ability to rapidly respond to scandals or disruptions, minimising erosion to consumer trust (Hatton, 2015).

Figure 7. Own work

5.0: Discussion

5.1: Theoretical implications

This dissertation contributes to scholarly discourse on blockchain technology and supply chain management (SCM) by analytically exploring the implications of a blockchain traceability system in the luxury apparel industry. This exploration aligns broadly with the existing literature on the topic, which holds that blockchain technology has vast potential as an effective solution for enhancing traceability in complex supply chains (Agrawal, 2021). This study bridges a notable gap within academic literature by using the lessons learned in the agri-food sector to explore the implications of adoption for an under-researched industry (Badzar, 2016).

5.2: Practical implications

Elimination of intermediaries and improvement of supply chain processes

The integration of blockchain technology into the luxury sector's supply chain presents a pivotal opportunity to eliminate intermediaries, enhance traceability, and streamline management processes. Despite the leverage of digital platforms, the luxury apparel industry remains overcomplicated and relies on numerous intermediaries (Song et al., 2019). Both academics and industry managers concur on the necessity of improving supply chain processes, recognising the potential of blockchain solutions to provide the transformation needed (Al-Talib et al., 2020). Several studies have shown that blockchain can enhance supply chain efficiency by eliminating unnecessary intermediaries (Casado-Vara et al., 2018; Al-Talib et al., 2020; Wang et al., 2019). The process of disintermediation through blockchain technology (Tonnissen & Teuteberg, 2020) enhances transparency, traceability and visibility within the supply chain, whilst also providing protection against counterfeiting (Wang et al., 2019), hence leading to a reduction in operational uncertainty (Xu et al., 2019). The luxury industry requires the tracking of products throughout the supply chain in order to maintain high quality and verify product origins (Shen et al., 2020). Furthermore, brands need to demonstrate their environmental commitment to consumers (Ho et al., 2016), which can significantly enhance their brand image. Despite these advantages, the luxury apparel industry remains hesitant to adopt blockchain technology. Regardless, the promise of improved transparency and traceability underscores the importance of blockchain in reinforcing the sector's quality and sustainability standards.

Importance of industry leadership

Leadership, both within LVMH and in its interactions with external stakeholders, including supply chain constituents, has been found to be a critical enabler for the adoption of blockchain technology (Hastig & Sodhi, 2020). Effective leadership can be demonstrated in two ways: Internally, by motivating supply chain partners, and externally, by championing the benefits of the technology (Catalini & Gans, 2016; Chow, 2018; Jeppsson & Olsson, 2017). Firms are generally more inclined to commit resources to blockchain initiatives when there is already industry-wide acceptance, typically led by prominent entities (Petersen

et al., 2017). The agri-food sector exemplifies this dynamic, with blockchain adoption driven by the retail giant Walmart, thereby paving the way for smaller actors to follow suit (Lefroy, 2018; Leng et al., 2018; Tian, 2017; Britchenko et al., 2018; Kim & Laskowski, 2017; Thomassen, 2019). For blockchain initiatives to succeed in the luxury apparel sector, LVMH must take on a leadership role, as these efforts are likely to falter without the active engagement of its supply chain partners (Bateman, 2015). This leadership role entails communicating with supply chain stakeholders, disseminating challenges and opportunities, and drawing insights from existing blockchain implementations. As a result, LVMH can effectively spearhead the implementation of blockchain technology across its supply chain network.

Effect on counterfeit goods and grey markets

By examining the implementation of blockchain technology in the luxury apparel sector's supply chain, the potential to address the issues of counterfeit goods and the grey market is seen as promising. Blockchain technology's anti-counterfeiting potential is inferred through solutions of data traceability and property rights protection (Liu et al., 2020), although effective application must comply with governmental regulations (Xu et al., 2019). Crucially, the adoption of blockchain requires a transformation in the luxury apparel industry's collaborative practices and integrity (Soon & Manning, 2019). Furthermore, Blockchain's swift and provable fraud detection enhances transparency and reduces financial losses (Guercini & Runfola, 2009). As one of the sectors most impacted by counterfeiting and grey market activities (Hou et al., 2020; Choi, 2019), the luxury industry stands to benefit significantly from blockchain solutions (Kshetri, 2018). Despite the acknowledgment of persistent constraints and the slow transformation of traditional supply chains (Helo & Hao, 2019), it is noted that digitalisation and evolving consumer demands renders blockchain's application as increasingly advantageous.

Barriers to adoption and contextual factors

In exploring the adoption of blockchain solutions within the luxury apparel sector, it has become apparent that several contextual factors can influence its implementation. Firstly, the luxury apparel industry might resist rapid change due to its traditional structure. Secondly, luxury brands may be reluctant to embrace the degree of openness and transparency required to effectively integrate blockchain technology into their operations. Although the adoption of disruptive technology aligns with the luxury apparel industries values (Yeoman & McMahon-Beattie, 2018), approval typically hinges on demonstrable financial benefits, necessitating short-term returns on investment (Frizzo-Barker et al., 2020). This is consistent with sources gathered in the literature review, whereby executive approval has a significant impact on the implementation of blockchain technology. Luxury brands are more inclined to adopt blockchain technologies when they are perceived to enhance performance (Maersk, 2018), and contribute to revenue streams (Deloitte, 2018). Several obstacles can impede the adoption process: for example, potential cultural resistance at the industry or country level, lack of digitalisation among suppliers, and trust issues (Kano & Nakajima, 2018; Kshetri, 2018; Reyna et al., 2018). The openness of blockchain, which can enhance traceability and transparency, might also present challenges due to the competitive nature of the luxury industry and its general lack of collaboration (Kshetri, 2018). In addition, increased complexity can negatively affect supply chain performance, particularly for blockchain solutions, which are not yet widely adopted in the luxury sector (Qrunleh & Tarafdar, 2014). The knowledge gap regarding blockchain technology further complicates acceptance among non-techically oriented decision-makers and employees (Baudier et al., 2021). However, these concerns can be addressed through a greater understanding of private blockchain frameworks and the benefits of the technology, which could alleviate hesitations surrounding its implementation (Wamba et al., 2020; Lu, 2019).

Solving issues of counterfeit goods and the grey market

By examining the implementation of blockchain technology in the luxury apparel sector's supply chain, the potential to address the issues of counterfeit goods and the grey market is seen as promising. Blockchain technology's anti-counterfeiting potential is inferred through solutions of data traceability and property rights protection (Liu et al., 2020), although effective application must comply with governmental regulations (Xu et al., 2019). Crucially, the adoption of blockchain requires a transformation in the luxury apparel industry's collaborative practices and integrity (Soon & Manning, 2019). Furthermore, Blockchain's swift and provable fraud detection enhances transparency and reduces financial losses (Guercini & Runfola, 2009). As one of the sectors most impacted by counterfeiting and grey market activities (Hou et al., 2020; Choi, 2019), the luxury industry stands to benefit significantly from blockchain solutions (Kshetri, 2018). Despite the acknowledgment of persistent constraints and the slow transformation of traditional supply chains (Helo & Hao, 2019), it is noted that digitalisation and evolving consumer demands renders blockchain's application as increasingly advantageous.

6.0: Conclusion

The contemporary luxury apparel industry is navigating an era where consumer concerns regarding the origin, authenticity, and sustainability of products are increasingly pronounced. This shift in consumer attitudes is occurring alongside numerous international scandals that have significantly tarnished industry reputations and diminished consumer trust. These challenges emphasise the need

for transparent, sustainable practices that can restore consumer confidence and improve environmental and social sustainability. Despite numerous barriers to the adoption of blockchain technology, the findings of this research demonstrate significant potential for the implementation of a blockchain traceability system in the luxury apparel industry. The properties of blockchain provide solutions to various traceability issues discussed in this dissertation, with a case study of the agri-food industry highlighting the benefits blockchain adoption can have upon supply chain management.

6.1: Limitations of findings

Whilst this exploratory study offers valuable insights into the potential of blockchain technology to address traceability challenges in the luxury apparel industry, it is important to acknowledge several limitations that may affect the validity and applicability of these findings. Firstly, the study primarily relies on qualitative data, which, although provides rich contextual detail, may lack statistical rigour and representativeness of quantitative approaches. In addition, the luxury apparel industry is characterised by significant heterogeneity in terms of brand positioning, supply chain structures and market dynamics (Asare et al., 2016), which may limit applicability across different segments of the industry. Furthermore, the focus of this research on the potential benefits and challenges does not consider further developments or alternative solutions in the future. Therefore, the findings may not be relevant when the technology is developed further. Finally, the study's contextual focus may limit the generalisability of findings to other sectors, where traceability challenges and blockchain adoption dynamics may differ. Despite this, this study can provide a valuable foundation for future research and industry practice in exploring blockchain's role in enhancing traceability and sustainability in the luxury sector.

6.2: Areas for further research

The findings of this exploratory study have highlighted several opportunities for further research into the implementation of blockchain technology within the luxury apparel industry. Given the emerging nature of blockchain literature and the commercial interest in blockchain adoption, numerous avenues can be explored to further explore this application. Firstly, quantitative methodologies can be used to validate the findings of this research to provide statistical evidence of blockchain's impact on traceability issues. Such studies can include large scale surveys or experiments to assess the specific befits and challenges associated with blockchain technology across different segments of the luxury apparel market. Additionally, the investigation of consumer perceptions and behaviours in response to blockchain-enabled traceability features in the luxury apparel industry is a literature gap that may offer valuable insights into the adoption of the technology. Understanding consumer attitudes towards blockchain can assist brands in effectively communicating the value of this technology to their consumers, potentially enhancing consumer trust and loyalty. Further research could also explore the long-term effects of blockchain adoption upon corporate sustainability practices and governance. This could examine whether blockchain would have a significant impact in improvements to sustainability outcomes in the long run.

Appendix A – Ethics Approval Form

School of Economics, Finance & Management

Application for Ethical Approval – UG Dissertation Students 2020

All research involving human participants[1] requires University approval. You are not permitted to begin conducting your research until ethical approval has been granted by your supervisor and, if necessary, by the School or Faculty Research Ethics Committee. This process is designed to help you reflect on your ongoing responsibilities as a social science researcher and it is not meant to be an obstacle to good research. Notes to help you think about the ethical dimensions of your research are given at the end of this document.

Students who are using anonymised secondary data or reviewing literature only

If you are only using anonymised secondary datasets, then please complete Part A of this document and submit it via email to your supervisor for signature. The completed form signed by both you and your supervisor must be submitted to Blackboard by the deadline and included in the appendices of your dissertation or assignment. Failure to do so may mean your Dissertation will not be passed.

Students who are collecting primary data or using non-anonymous data

If you are collecting primary data or using non-anonymous data such as social media posts, then please complete this form in full and submit together with a copy of your data collection instrument (e.g. questionnaire/interview schedule) and consent form (if separate to your data collection instrument) via email to your supervisor for review and signature. The completed form signed by both you and your supervisor must be submitted to Blackboard by the deadline and included in the appendices of your dissertation or assignment. Failure to do so may mean your Dissertation will not be passed.

[1] The ESRC Research Ethics Framework defines human participants as including living human beings and human data and records (such as, but not restricted to, medical, genetic, financial, personnel, criminal or administrative records and test results including scholastic achievements).

Supervisor signature: If the ethics application is for a UG dissertation, then your supervisor should sign the form.

If your research involves a sensitive topic or data collection from vulnerable groups, then your supervisor will request you to submit your approval form to the School's Research Ethics Committee.

If you have been told you must submit an application to the School's Ethics Committee then please **contact Dr Anita Mangan** for guidance in the first instance – Anita.Mangan@bristol.ac.uk.

Not all sections of the form will necessarily apply to your research. Where you consider this to be the case please indicate with 'not applicable'.

PLEASE NOTE – If your research project changes significantly, then you must ask your supervisor or unit director whether you need to submit a new version of this ethics review form.

Name and student ID: Lucas Fadden, 2164833

Email: ob21626@bristol.ac.uk

Degree course: Management

Name of dissertation supervisor: Chandrasekararao Seepana

Project title: An exploratory study of blockchain technology implementation to address traceability challenges in the luxury apparel industry

Project start and end dates (e.g. award of degree): 15/09/2023 – 31/05/2024

Please provide a brief summary of your project within the box below

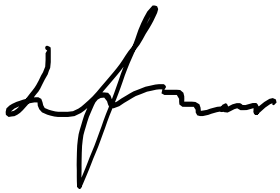
This project explores the possible utilisations of blockchain technology in the luxury apparel industry with the intention to solve the issues and challenges faced by the industry due to a lack of traceability. This dissertation uses a comparative case study analysis to analyse the implications of a blockchain technology traceability system on the 4 industry challenges identified in the study,

Part A

	Ye	No
1. Does your research **only** involve the use of large, secondary an anonymised datasets or a review of published literature?	X	

If YES, you do not need to complete Part B of this form. You and your supervisor should sign below.

If NO, do not sign this page. You also need to complete Part B of this form and submit it to your supervisor for review and signature.

Student name and signature: Lucas Fadden 

Date: 10/02/2024

Supervisor or unit director name and signature: Chandra Seepana 

Date 21/02/2024

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