Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

ERVIN ANDERSON

Blockchain's Impact on Parcel Tracking Systems

DEGREE PROGRAMME IN LOGISTICS
2024

ABSTRACT

Author	Type of publication	Date
Ervin Anderson	Thesis, UAS	May 2024
	Number of pages	Language of publication:
	42	English

Title of Publication

Blockchain's Impact on Parcel Tracking Systems

Degree Programme

Degree Programme in Logistics

Abstract

Due to the rapid digitalisation of the global economy, the supply chain sector is facing significant challenges. Blockchain technology, better known for its use in cryptocurrencies may be a potential solution to these problems.

The aim of this thesis is to investigate blockchain’s capability to enhance parcel tracking and data integrity. The qualitative research method will be integrated through literature reviews, case studies and empirical research.

The results demonstrate, that blockchain’s immutable and decentralised nature is not only capable to increase security and transparency, but also provides stakeholders with precise and real-time tracking information, thus helping to reduce inefficiencies and losses.

Like with any other innovation, there are also existing challenges to overcome, including blockchain’s technological complexity, the absence of standardised protocols and concerns regarding the stakeholder’s privacy.

To address these obstacles, the thesis promotes the idea of collaboration between logistics industry leaders and policymakers. It highlights the importance of conducting further research on scalable blockchain solutions and implications on security, which can be brought by quantum computing.

This study aims to find whether blockchain technology can influence the efficiency and resilience of the modern supply chain ecosystem.

Keywords

Blockchain, Parcel Tracking, Supply Chain Management, Smart Contracts, Decentralised Ledger, Logistics, Data Integrity, Technological Adoption

CONTENTS

LIST OF ABBREVIATIONS

BT - Blockchain Technology

DLT - Distributed Ledger Technology

IoT - Internet of Things

RFID - Radio-Frequency Identification

GPS - Global Positioning System

PoW - Proof of Work

PoS - Proof of Stake

ERP - Enterprise Resource Planning

CRM - Customer Relationship Management

SCP - Supply Chain Planning

MES - Manufacturing Execution Systems

1 INTRODUCTION

1.1 Research Background

Over the last ten years, the supply chain has encountered serious challenges. Rapidly digitalizing global economy requires increased transparency, efficiency, and security. Blockchain technology, firstly known for its use in the world of cryptocurrencies, has emerged as an alternative solution to these challenges. Blockchain has to offer unique characteristics like immutability, decentralisation, and transparency. These features have the potential to transform supply chain management. This can be achieved by means of the improved parcel tracking systems and data integrity. However, like with any other innovative technology, there are obstacles on the way to blockchain mass adoption, including significant ethical considerations and organizational barriers.

This thesis explores the revolutionary potential of blockchain technology in scope of supply chain management. The focus is on the overall logistical landscape and improving parcel tracking. Research attempts to provide answers to critical enquiries, like ability of the blockchain technology to enhance the accuracy and reliability of parcel tracking, be able to minimize losses and inefficiencies in the supply chain and overcome the challenges and limitations associated with its mass adoption.

This study aims to provide a comprehensive overview of blockchain's technology capabilities by integrating insights from existing scholar literature, real-world case studies, and empirical research.

1.2 Problem Statement

In recent years, the worldwide package shipping volume has seen enormous growth. According to the latest studies, the number of parcels sent from 2016 to 2022 has surged by nearly 150 per cent, amplified by the COVID-19 pandemic. (Zegras, 2023)

However, the increase in parcel volumes brings to light a tightly related problem: the increasing number of packages that did not reach their intended recipient. Every tenth customer encountered theft or loss of their parcel, which is more than a billion disappeared items globally. (Morell, 2023)

The worldwide parcel distribution networks require innovative solutions to improve the efficiency and reliability of the international package delivery system. Blockchain technology can serve as a “remedy”.

This study aims to investigate the effectiveness of blockchain technology in reducing parcel loss and theft probability and improving parcel tracking accuracy.

1.3 Thesis Objectives and Research Questions

The primary objective of the research is to get a profound understanding of how can distributed ledger technology (blockchain) improve parcel tracing in the supply chain business. The expected outcome is a detailed informative guide, which is based on the literature review and visionary interviews with the key players in the local logistics field and can be used by companies, who are considering deploying blockchain technology. The outcome cannot be verified.

There are three research questions:

1. **How can blockchain technology revolutionize parcel tracking and data integrity in supply chain management, while addressing privacy and ethical considerations?**
2. **In what ways does integrating blockchain with IoT and other technologies contribute to sustainable and resilient supply chain operations?**

3. **What are the key barriers to the adoption of blockchain in supply chain management, and how can they be overcome to foster stakeholder trust and collaboration?**

1.4 Scope of the study

In my research, I will focus on the theoretical part of blockchain's influence on the logistics delivery sector, also covering aspects like blockchain architecture, types, and key characteristics.
The study will explore possible technical challenges and solutions awaiting on the way of blockchain integration into already existing supply chains.
The research will not discuss topics like in-depth technical blockchain implementation aspects, profound legal and regulatory framework and long-term predictions related to blockchain use in the logistics sector.

1.5 Theoretical framework

The main part of my theory section is based on the blockchain and package tracking systems literature review. It will explain to the reader, what exactly the blockchain is and how it can co-work with package delivery services, what are the benefits and possible issues, arising from this cooperation.
In subsequent chapters, I will discuss real-world case scenarios, where blockchain is already used by logistics companies.

1.6 Methodology

For the research, I used the qualitative method along with the inductive approach. The qualitative method gives flexibility, allowing the incorporation of interviews and writer's own observations. Also, it allows secondary research, when data can be collected in the form of video, audio, or image format.(Bhandari, 2023)
According to (Thomas, 2003) article, inductive approach allows the main findings to emerge naturally from the most important and significant ideas found

in the data. This approach does not rely on rigid, predetermined methodologies, allowing the researcher to uncover unforeseen discoveries.
The empirical part of the study contains two interviews with representatives from the local delivery companies. They will give valuable insight into their views on blockchain technology implementation in their delivery business.

2 THEORETICAL BACKROUND

2.1 Blockchain technology: An overview

Initially, the blockchain was introduced in 2009 by Satoshi Nakamoto (a pseudonym for an individual or possibly a group) for a virtual currency called Bitcoin. (Karjian, 2023) Following that, it has seen significant growth and started to be recognised as a symbol of security, effectiveness, and openness among many different industries, including finance, healthcare, luxury business and supply chain management. Nowadays it can be even used for identity confirmation or in voting systems.
Blockchain is a distributed digital ledger, which offers an impressive level of security and transparency. It enables the recording of transactions across numerous user's computers, guaranteeing that any further changes are impossible. This ensures that every participant on the network gets transaction update simultaneously. (McKinsey, 2022)
When a blockchain user initiates a transaction from their wallet application, it automatically joins the pool of pending transactions, miners select these transactions to create a new block and add it to the blockchain.

Miners have a key role in the blockchain network. They use powerful computers to solve complicated mathematical problems, this process is called proof of work. This crucial effort is needed for validating transactions and guaranteeing blockchain security. When mathematical problem is successfully solved, miners are granted permission to add newly generated block to the blockchain.

Once the new block is formed, it goes through a validation process by the network, which includes verification using hash input and signatures.
The outcome of the successful mining is not only the new block in the chain but also the reward for the miners with a certain amount of cryptocurrency, providing an incentive for their contribution to the network's integrity and security. (Ismail & Materwala, 2019)

When a new block is verified and consensus is reached, it is successfully added to the blockchain, all subsequent blocks serve as a confirmation of this addition. This process is visualised in the Figure 1 below.

On the blockchain, every block stores a certain amount of information, and every new block has a connection to the previous block, resembling a chain of blocks, which is where from the actual name "blockchain" comes. Information within blocks is securely protected by cryptographic techniques. The blockchain itself is maintained by a decentralised computer network, called nodes, the primary function of the nodes is to authenticate and validate every transaction, thus data's security on the blockchain can be guaranteed.(Tripathi et al., 2023)

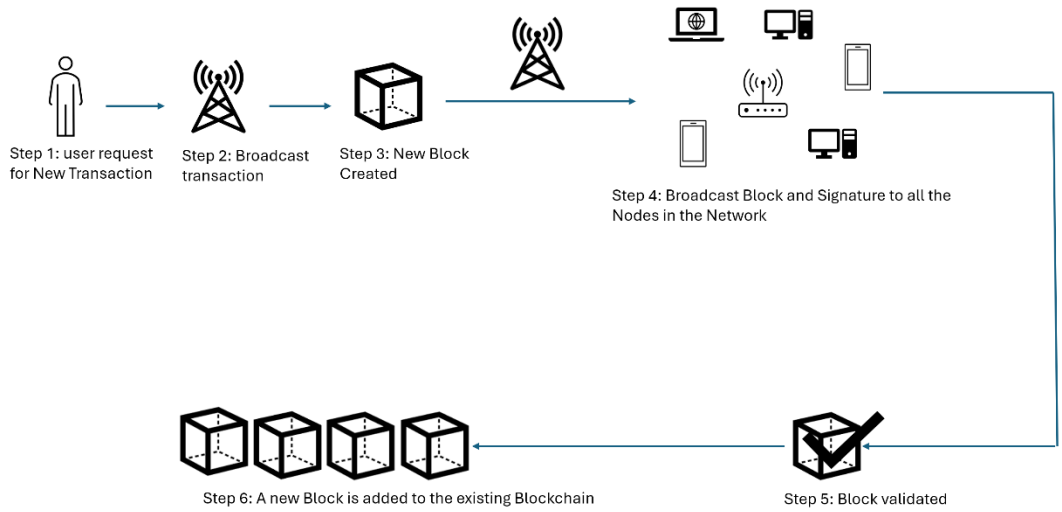

Figure 1: The visualised process of creating new block. Adapted from (Tripathi et al., 2023)

Each block in the blockchain consists of two parts: the header and the body, the header has important metadata like timestamp (the exact time, when the neb block was created), a cryptographic hash, which is linked to the previous block, and the solution to a complicated mathematical puzzle. Simply speaking, the hash acts as a cryptographic signature, which signs every new created block. The body of the block contains transaction data or other relevant information.(Network Encyclopedia, 2023)

Blockchain introduces two important concepts such as “immutability” and “smart contracts”. The term immutability means that the data once recorded on the shared ledger cannot be altered in the future, but it is auditable, which can grant trust among all stakeholders. Furthermore, blockchain allow selective access to relevant data for specific parties.

Smart contracts are automated, self-executing contracts with the terms of the actual agreement written in code on a blockchain. They automatically conduct transactions when predefined conditions are met, ensuring transparency and security without the need for middlemen, as a result, transactions become more efficient and less prone to errors. (IBM, 2024)

In the logistics and delivery business smart contract can be exemplified by a delivery agreement between a manufacturing company and a shipping provider. A scenario where the payment to the delivery company will be released only if goods are delivered on time and in pristine condition. All-important delivery details like time of arrival, address and condition of goods can be encoded into the smart contract. Sensors in the delivery package or in the vehicle can automatically update the blockchain with real-time data. In case, the package arrives on time and sensors confirm their condition as per the agreement, the smart contract simultaneously can process the payment to the delivery company. This technology streamlines the entire process and additionally ensures transparency and trust because the contract executes only when all agreed conditions are met. This in turn will reduce disputes and enhance the efficiency of the supply chain.

2.1.1 Blockchain technology use in different sectors

The utility of blockchain technology is not limited only to cryptocurrencies. It serves as a fundamental innovation for many applications in multiple industries.

In the healthcare sector, blockchain provides a secure platform, which stores and shares patient's records, thereby protecting data integrity and patient confidentiality. Reliable and up-to-date information provided to healthcare professionals can improve treatment outcomes. For instance, Estonia has been using blockchain technology in their healthcare system, it is called e-Health.

This electronic health record consolidates data from various healthcare providers into one single nationwide online data bank, which is accessible for each patient. This setup provides doctors with seamless access to patient records, including real-time test results and X-rays from a centralised electronic file. The integrity and security of these records is safeguarded by KSI blockchain technology. (e-estonia.com)

Another use case is in the real estate business. Real estate transactions can be secured using tokenisation and use of smart contracts. It speeds up processes and maintains transparency in dealings, it also allows investors to buy shares or tokens in properties without the need to purchase entire properties.

The platform RealT in the United States offers users to buy token which represent shares in rental properties, enabling them to earn a share of the rental income. (realt.co)

The blockchain technology can serve as an intellectual property protection. Tamper-proof record of content creation and ownership can protect intellectual property for artists, musicians, and authors. This technology can also automate royalty payments, thus ensuring every creator is fairly compensated for their work. Mycelia for music and KodakOne are well known platforms, which offer authors intellectual property protection possibility.

2.1.2 Classification of Blockchain

According to (Lin & Liao, 2017), there are three types of blockchain: private, public and consortium.

Private blockchain is a centralised blockchain. This type of blockchain is exclusive to a single organization or its subsidiaries within the same cluster of groups. Access to read and submit transactions is restricted only to these entities. It is suitable for businesses, which would like to use the network only for internal purposes. IBM and Hyperledger Fabric are the examples of the private blockchains.

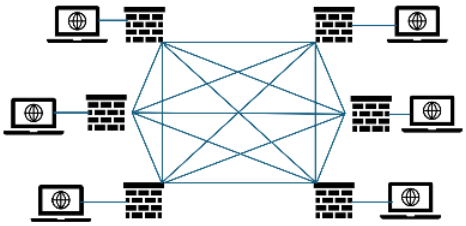

Figure 2: Private blockchain. Adapted from (Lin & Liao, 2017)

Public blockchains are entirely open for public use and decentralized. Anyone can join and participate in the core activities of the network, such as verifying transactions, producing new blocks, and reading the complete blockchain. Bitcoin and Ethereum are well-known cryptocurrency world examples of public blockchains. Due to their decentralised nature, they have a high level of integrity and are regarded as the most secure networks. They are ideal for cases where transparency and decentralization are critical, such as in cryptocurrencies.

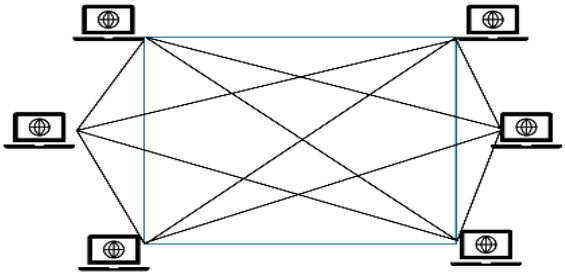

Figure 3: Public blockchain. Adapted from (Lin & Liao, 2017)

Consortium blockchain is the type of network, when several companies create a consortium, which has access to data readability and can submit transactions. Data in these blockchains can be partially open or private, due to their semi-decentralised nature. It is mostly used in the business-to-business category.
Contour, TradeLens and Energy Web Foundation are examples of consortium blockchains.

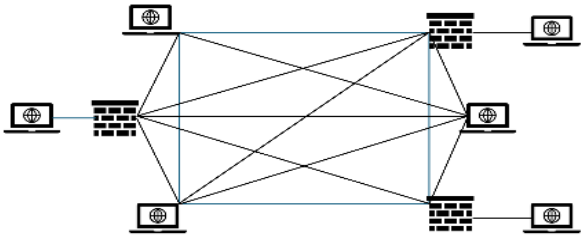

Figure 4: Consortium blockchain. Adapted from (Lin & Liao, 2017)

Blockchains are categorised into two distinct networks: permissionless and permissioned blockchains.
Permissionless networks are open and decentralised, new participants can view transactions and join without restrictions. Users do not need to reveal their identities to participate on the network. Bitcoin and Ethereum are traditional examples of permissionless networks.
Permissioned networks do the opposite of the permissionless networks. They restrict anonymous network access; new participants must obtain invitation to be able to join the network. Hyperledger Fabric and R3 Corda are examples of permissioned networks. (Rennock et al., 2018)

Additionally, to three main types of blockchain, one more type of blockchain has emerged recently. It is called hybrid. In the hybrid network all three main blockchains can work in combined manner, to better facilitate transactions. (Kumar & Yeboah, 2019)
Dragonchain is an example of hybrid blockchain. It was developed by The Walt Disney Company, to allow businesses keep their sensitive data private, but at the same time enabling them to interact with public blockchains like Ethereum. (Dragonchain, 2024)

2.1.3 Consensus mechanisms

In simple terms, consensus mechanism in the blockchain technology is a system that helps to achieve agreement on a single network between different participants. It plays crucial role in verifying transactions, prevents problems like double-spending and ensures that every stake holder's copy of the digital ledger is consistent with other copies.
Two most common types of consensus mechanisms used in blockchains are Proof of Work (PoW) and Proof of Stake (PoS).

Proof of Work was initially used by Bitcoin cryptocurrency and many other public blockchains. It is the first and one of the most secure consensus mechanisms. In this type of system, "miners" use powerful computers to solve complicated mathematical puzzles, to be able to create a new block and verify transactions. As a reward miners get transaction fees and new coins created with each new block (block rewards).
Proof of Stake works on a principle where network users lock up their digital currency as a stake to be able to validate a new block in the blockchain. Validators, who are staking more coins, have more chances to build a new block. Unlike the block rewards in the Proof of Work consensus, in the Proof of Stake system participants earn transaction fees, instead of new coins.
A prominent Proof of Stake chain example is Ethereum, which changed from PoW to PoS in 2022. (crypto.com, 2022)

2.2 Blockchain in Logistics and Supply Chain Management

Successful logistics operations need tight collaboration between many different stakeholders, at the same time the constant flow of information, physical goods and money movement must be precisely monitored. There is a big opportunity for the blockchain technology to modernise supply chain ecosystem.

Blockchain provides equal information access and transparency to all involved players. Everyone in the supply chain has clear visibility into transactions, this means that parcel's current location with all necessary documents and shipping details is available in real-time.
This immutable technology guarantees the security of every transaction along the supply chain. Once data is recorded, it cannot be altered later, thus making it trustworthy for every participant. Originality of the product can be verified through blockchain and traced back to the initial producer. This feature is irreplaceable in the luxury brands business, where a substantial number of counterfeit items are produced annually. (verbbrands.com)
As I mentioned earlier, using a "smart contracts" blockchain can facilitate payment processes. Digital agreements can automatically execute financial transactions when all conditions are met. This automated technology leads to better overall efficiency of supply chain management. (Möller, 2023)
As we move to examine parcel delivery more closely, understanding blockchain's role in addressing delivery challenges becomes key to advancing operational efficiency and customer satisfaction.

2.3 Parcel Delivery

As the online shopping and modern supply chain management are revolutionizing, parcel delivery industry is starting to play crucial role in connecting businesses with their end customers.
For parcels to be delivered on time, reliably and at a low cost, delivery systems must work efficiently and without hiccups. Seamless end-to-end delivery process that is keeping track of inventories and optimizes routes is in need for support by advanced logistics, progressive technology, and data analytics.
One possible solution to bring transportation systems up to date is the integration of blockchain technology, known for its unmatched ability to integrate large amounts of data, allow real-time parcels tracking and automate payment systems, blockchain can help to solve emerging supply chain issues.
In the next chapter, I will explore the specific challenges that blockchain technology aims to resolve.

2.4 Challenges in Parcel Tracking Systems

To make sure that their customers are getting top-quality service, the courier companies must overcome several obstacles.
Here is the list of most evident challenges to tackle:

1. Insufficient verification mechanisms. In most cases, when package is delivered to the customer, the courier is asking to sign paper documents or apply electronic signature into the handheld computer, unfortunately both methods lack adequate verification mechanisms. There is no guarantee against the forgery and eventually it will be hard to securely ensure parcel receipt. The working solution for this issue could be the implementation of blockchain's immutable ledger, this innovative technology is capable of recording deliveries in a secure and verifiable manner.

2. Courier trustworthiness can be still an issue. The delivery process reliability heavily depends on courier credibility, but current systems fail to adequately verify their trustworthiness. This flaw can lead to potential risks of mishandling and theft. Blockchain technology offers workable solution, by means of transparent and unchangeable transactions logs.

3. Dependency on third-party couriers. During the busiest times, such as Black Friday or Christmas, businesses often rely on additional various courier services, which can lead to inconsistencies in service and tracking. This dependence makes it harder to manage delivery and lowers the reliability of the service across regions. Using a decentralized network, Blockchain can streamline the integration of different courier services.

4. Issues with centralised systems. Centralised tracking systems are prone to privacy breaches, data manipulation, and cyberattacks, because all the data is monitored by one authority. This issue can be addressed by blockchain's decentralised nature, as tens or even hundreds of different nodes oversee securing network processes.

5. Concerns with privacy and security. Concerns are rising with the way delivery services handle customer’s personal information. Blockchain's sophisticated encryption and privacy protocols offer a strong solution to the challenges associated with managing personal information.(Hasan & Salah, 2018)

In the next section we are moving from identifying package delivery and tracking challenges to exploring actual blockchain technology applications in the logistics sector.
Following chapters illustrate how blockchain might theoretically address logistical issues, drawing on academic theories, actual use cases, and speculative models. While actual implementations in the logistics sector are still limited due to the technological novelty, these theoretical applications offer insights into blockchain's capacity to enhance transparency, efficiency, and reliability in parcel delivery.

2.4.1 UPS

UPS, a century-old US based logistics leader decided to use blockchain technology as a possible solution to streamline the complicated global supply chain management. UPS filed a patent application that describes the use of blockchain and Distributed Ledger Technology (DLT), to help improve the flow of shipments in global supply network involving various carriers.
Innovative solution aims to tackle the logistical issues of coordinating shipments, particularly when specific handling requirements are needed.
UPS considers creating a blockchain-based system, that will automate the parcel routing process. When a package enters that system, it automatically selects the most efficient route, based on the capabilities of connected shipping providers. As the parcel is moving towards the final destination, every step will be recorded on the blockchain ledger. This technology allows to provide better integrity and transparency of delivery processes, same time enabling the evaluation of each service provider in meeting their contractual obligations.

Additionally, UPS’s concept involves utilising smart contracts across interconnected DLT networks, to enable automatic value transfers between different stakeholders in the supply chain. By utilising digital currencies, carriers and partners will be paid in real-time, thus enhancing transaction efficiency. (Wilmoth, 2021)

2.4.2 Real-World Application of Blockchain in Logistics: FedEx's Initiative

FedEx, a well-known global parcel delivery provider, has successfully integrated blockchain technology into its supply chain management. Technology is used to increase the level of traceability and reliability of the records, which is crucial for resolving dispute cases with FedEx customers.
This strategic move from the “big” logistics player addresses common challenges in logistics, such as improving transparency and security in data management.
By joining the Blockchain in Transport Alliance (BITA) Standards Council, FedEx makes an innovative move ahead of its primal competitors and shows the direction for further improvements and digitalisation across the logistics sector.
FedEx has publicly acknowledged the significant impact of blockchain technology on the supply chain management mechanisms and potential to transform logistics operations. (Musienko, 2023)

These practical implementations by UPS and FedEx underscore blockchain implementation not just in theory but in real-world applications. To fully understand the scope of blockchain’s impact on the package delivery business, it is also important to introduce academic research regarding this topic. Such studies offer a much broader perspective on potential blockchain technology use and future directions within the logistics sector.

2.5 Blockchain Technology Adaptation Challenges

While blockchain technology adoption promise remarkable advantages in transparency, security and integrity, its implementation brings several challenges across various industries, including the supply chain management. This overview addresses common obstacles associated with the blockchain implementation.

Administrative barriers are one of the main challenges, which are existing due to the fact, that unified legal framework is missing. Similar issue is with the efficient regulatory schemes for overseeing blockchain technology application. The absence of governmental incentives or support, coupled with aforementioned issues, diminishes enterprise's interest in blockchain adoption. Sociocultural factors in emerging economies could also complicate further adoption because differences in education, poverty levels and age affecting the proper understanding and use of blockchain.

Technological challenges are another important obstacle. The lack of technological standardisation and infrastructure are minimising blockchain's global adoption potential. Technology's immaturity in data security brings problems with privacy. It might be hard to incorporate immutable nature of blockchain with existing business systems, which can lead to incorrect data perpetuation. Due to the fixed structure of smart contracts, the broader development is required to connect them with supply chain management strategies.

Industrial obstacles are also remarkable problem. Collaboration issues and reluctance of the different key players to engage with the innovative technology are paramount. There is still not enough evidence of benefits provided by blockchain for logistics sector to convince major players to join the innovation. Reaching an agreement among many stakeholders may be a difficult task.

Organisational issues can be decisive for the companies with the limited budget. The high initial costs, alongside training and maintenance expenses deter companies from blockchain implementation. Limited resources like human expertise and technological infrastructure can further obstruct blockchain's mass adoption. (Duan et al., 2024)

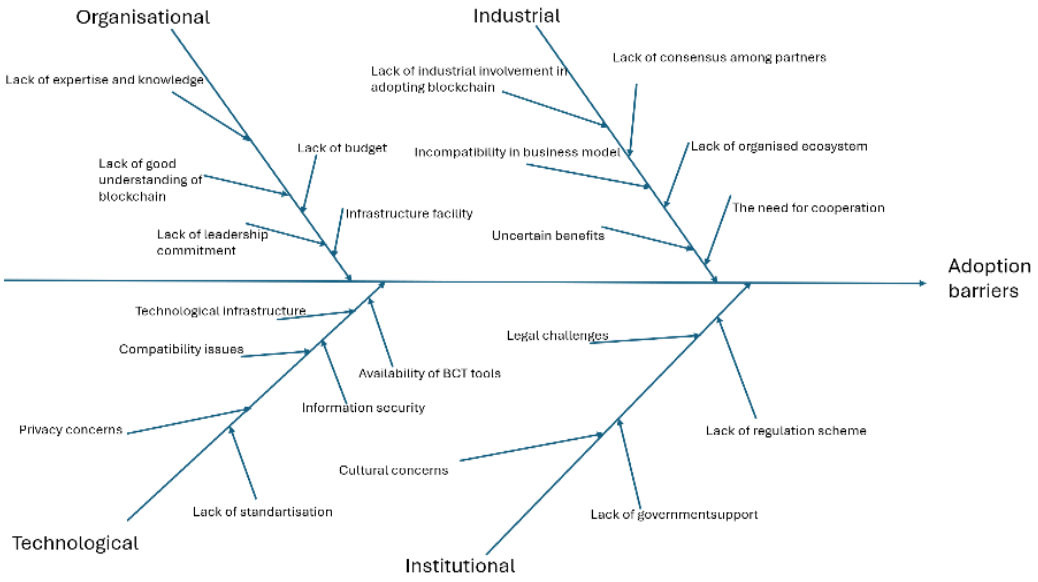

Figure 5: Blockchain technology adoption challenges in supply chain management. Adopted from (Duan et al., 2024)

By recognising and addressing these challenges, the process of incorporating blockchain into supply chain management can be smoother and more efficient.

2.6 Ethical Considerations in Blockchain Technology

The emergence of blockchain technology marked the beginning of groundbreaking and unparallel level of security and transparency, however, the integration of this kind of technology into supply chain management needs to address critical ethical considerations.

Data immutability is one of the most important characteristics of blockchain, meaning that data once stored on it, cannot be altered, or changed in the future, it becomes immutable, guaranteeing trust and transparency. However, this strength has ethical challenges, especially when traditional supervision methods are not in place. The decentralisation that blockchain offers its users, lacks the protective role of the intermediary like banks, who can assist customers with recovery of lost data or payments. This issue requires development of the alternative, decentralised protective security measures, which can provide solution while keeping the decentralisation intact.

Another dilemma is privacy vs transparency. The implementation of blockchain's public ledger allows for the profound auditing of all transactions, which enables complete transparency. But this transparency can violate customers personal privacy. From an ethical standpoint there is a contradiction between the customer's privacy and public's right to information. In the industry like healthcare this tension is particularly pronounced, due to the fact, that personal data is extremely sensitive. Private or hybrid blockchains have the solutions, but they also have the responsibility to protect from unauthorised access and data breaches, while keeping the balance between right to information and privacy rights.

The so called "zero-state problem" is also well-known issue. It refers to authenticity of the of the data inserted into the initial block of a blockchain. Any unintentional error or deliberate falsification at this stage will have a permanent and unerasable impact. In the context of supply chain management, this distinction could lead to significant implications since it is coming to the choice between procurement of ethical raw materials or unintentional support of unethical actions. Thus, it is especially important ethically for blockchain developers and users to verify the first data coming on to blockchain and maintain clear communication over the legitimacy of the genesis block. (Blackman, 2022)

To summarise, while blockchain presents a significant advancement in logistics management, it is crucial to approach it with careful consideration of ethical implications. Resolving these problems is not only a sheer technological requirement but also a moral obligation to ensure that the full potential of blockchain is utilized in a way that it will give the industry needed boost while maintaining ethical principles.

2.7 Enhancing Cross-Border Parcel Tracking with Blockchain and IoT

This study conducted by (Li et al., 2023) specifically addressing the challenges faced in cross-border deliveries amid and following COVID-19 pandemic.

The application of blockchain technology in parcel tracking systems aims to overcome these challenges.

A distributed ledger technology will help to create a real-time online monitoring system for supply chain operations. Seamless interaction and transactions will be offered for all supply chain participants.

Proposed system goes beyond traditional tracking systems by assigning a unique digital identity to each parcel. This identity will be tracked from origin to destination and simultaneously recorded on the blockchain ledger.

Every step on the parcel's route, including handovers between the different carriers and checkpoints across the borders will be logged in to blockchain. Thus, integrity and transparency will be ensured for all stakeholders during each delivery stage.

To enhance system's tracking capabilities the Internet of Things will be integrated as well. IoT devices like GPS sensors and RFID tags attached to the parcel would continuously transmit the parcel's location, condition, and environmental factors to the blockchain network. Data will be updated automatically without human intervention; this will eliminate probable errors.

The use of blockchain in conjunction with IoT devices enables a dynamic and responsive tracking system. In case of unexpected circumstances, if initially planned route becomes impractical, the system can reroute the parcel based on real-time data from the IoT devices. The flexibility of this system ensures that the parcel is delivered in good order, even if it faces force major circumstances on the way to a destination.

The authors of the study received positive feedback from User Acceptance Testing (UAT). It gives confidence, that blockchain-based tracking system holds promise in addressing the logistical complexities of modern commerce, particularly in a post-pandemic world.

2.8 Blockchain-Enhanced Last-Mile Delivery

According to another research (Lobo et al., 2022), integration of the blockchain technology into the last mile delivery systems is a sophisticated solution, which can tackle complexities and inefficiencies associated with traditional logistics

models. Study emphasizes the deployment of smart contacts, optimization of the algorithms and a decentralised ledger system, for enhancing operational efficiency and sustainability.

The main point of the proposed solution is the blockchain's distributed ledger technology (DLT), which enables a transparent, secure, and immutable record of transactions data. It facilitates real-time tracking of parcel deliveries and reducing discrepancies in the logistics chain. Adoption of DLT eliminates the need for centralised control and promotes resilience of the delivery systems against systematic failures.

Smart contracts play an especially important role in automating the execution of agreements between different stake holders involved in the last-mile delivery process. The fleet providers and couriers are automatically assigned with the delivery tasks by means of self-executing contracts. Criteria of assigning is based on the geographical proximity, parcel size and carrier capacity. Automation is aimed to significantly reduce manual work and streamline the whole delivery process.

Figure 6 illustrates the automation process facilitated by smart contracts.

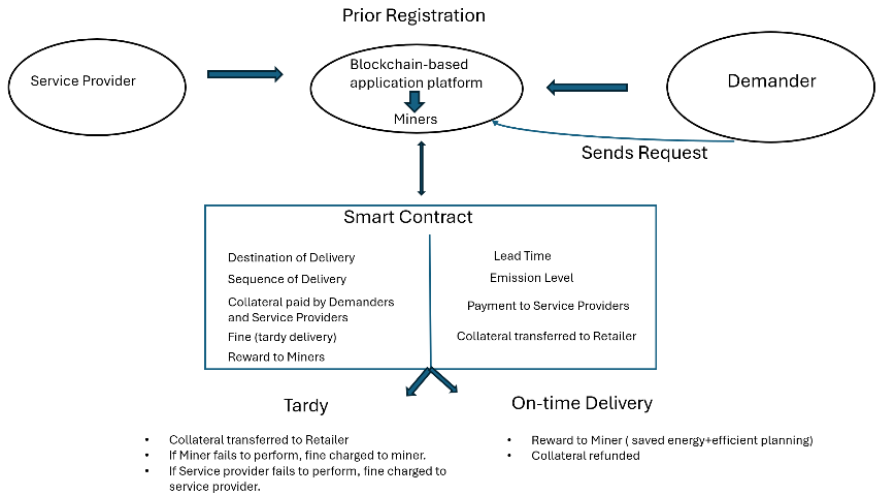

Figure 6: Smart contracts automation process. Adopted from (Lobo et al., 2022)

The advanced optimization algorithms are used to determine the most efficient delivery paths, which contribute to sustainability by minimising fuel consumption and reducing carbon emissions.
The technical framework consists of robust mechanism incentive alignment and performance evaluation.
Miners and validators within the blockchain network, are highly motivated to ensure the accurate and efficient allocation of deliveries. The proposed system has a reward and penalty arrangement when service providers are rewarded for on-time deliveries and punished for delays. This kind of incentive is promoting adherence to service level agreements.

To summarise previous statements, the integration of blockchain technology into last mile delivery can offer a robust solution to the challenges faced by traditional supply chain models. The use of DLT, smart contracts and optimization algorithms can help a lot with automation and reducing the possible errors. This approach is supposed to enhance operational efficiency and help to reduce environmental impact. The suggested blockchain-based system is a big step forward in the development of logistics and supply chain management because of how advanced this technology is.

2.9 Impact of Blockchain on Parcel Tracking Efficiency

The case studies of UPS, FedEx, as well as the research by (Lobo et al., 2022) and (Li et al., 2023) are showing how important is the influence of blockchain technology on parcel tracking efficiency in the contemporary logistics industry. With the help of blockchain and smart contracts, the actual package tracking can be achieved faster, more accurately and with the reduced cost.
Compared to traditional parcel tracking systems (barcode scanning and centralised data bases), which are still prone to multiple errors and slow resolutions, blockchain-enabled systems can offer greater productivity and customer satisfaction by offering real-time, transparent, and immutable tracking data records.

These case studies validate actual and theoretical advantages of blockchain in enhancing modern supply chain's efficiency.

2.10 Blockchain's Role in Enhancing Customer Satisfaction

The actual use of blockchain technology in the parcel tracking systems has shown positive effect on improvement the accuracy and data integrity, which in turn inevitably leads to higher customer satisfaction. This section, based on the (Hong & Hales, 2021) article, will explore how blockchain's innovative features help to achieve customer needs more efficiently, when compared to standard logistics systems.

As an example, use of blockchain technology in tracking the lifecycle of a product from first phase of its production to the stage of purchase, assures customers of the authenticity and ethical sourcing of their purchases. Such a high level of product history transparency cannot be achieved with the conventional tracking methods. And is very important to satisfy customer's concerns regarding the environmental and social impact of their buying decisions.

Blockchain can even offer the reward through cryptocurrencies for customers who are willing to participate in eco-friendly actions, such as recycling, further fostering a cheerful outlook toward sustainable practices.

The enhanced traceability features of blockchain technology can improve customer experience by providing the reliable product information, which can lead to higher purchase intentions.

With the help of effective customer relation management offered by blockchain, the companies have a chance to improve customers loyalty and retention, because consumers appreciate the added value of transparency and sustainability in their interactions with the varied brands.

Based on the previous information, there is a strong point, that blockchain technology can lead to more informed, satisfied, and loyal customer base.
(Hong & Hales, 2021)

3 EMPIRICAL FINDINGS

3.1 Analysis of Interview Data

This chapter presents the empirical research, which was carried out by using two interviews with representatives from local Finnish delivery companies.
The first interviewee, Petr Andrianov, is working as a Lead Product Designer at Starship Technologies (Starship Technologies is internationally transforming the last-mile delivery sector with its autonomous delivery robots) and second one, Goran Gjorgievski, holds the position of Head of Software Engineering at Posti Group Oyj.
The aim of the interviews was to gather information about blockchain current use, potential benefits, challenges, and prospects as seen through the lens of regional logistics players in Finland.
To get a well-rounded view of the technological adoption landscape, interviewees were selected from innovative tech-focused companies and from a traditional logistics background company.

3.2 Methodology

I have chosen to use a qualitative approach through semi-structured interviews. This method allowed me for in-depth discussions, while leaving more space to explore new relevant emergent topics. The open-ended questions facilitated comprehensive and prolonged responses, supporting the depth of the study.
For convenience and accessibility both interviews were conducted online.
Interview questions can be found in the appendices chapter.

3.3 Overview of Interview Findings

The selected respondents, Petr Andrianov from Starship Technologies, and Goran Gjorgievski from Posti Oyj, shared their valuable viewpoints, that are

reflecting how differently their companies approach possible implementation of blockchain technology.
According to Petr, the Starship Technologies do not use blockchain based logistics solutions at the moment and he is sceptical about its near-future implementation, due to technological and organisational challenges.
Goran mentioned that Posti Group is neither using blockchain technology as for now, but he was optimistic about its potential use in the upcoming years.
In this chapter I will highlight key perspectives on blockchain technology adoption within the local logistics sector.

3.3.1 Analysis of Interview with Petr Andrianov

Petr Andrianov from Starship Technologies outlined that, currently, his company is not considering the use of blockchain technology in the logistics part of their business. His perspective, as a Lead Product Designer, reflects the organization’s strategic technology decisions.

The main reason Starship Technologies currently avoids blockchain implementation is the cost consideration. Petr mentioned well-known financial challenges associated with BT initial adoption, he also pointed out that company’s size and budget constraints makes integration rather impractical at this stage of the development. Additionally, he indicated that thanks to the plethora of different cameras and sensors in their robots, they are receiving reliable real-time information, and BT implementation will be superfluous now.

This decision affects Starship Technologies by prioritising cost efficiency and operational simplicity. Even if it may restrict the potential benefits of BT, like enhanced security and transparency, the company will prefer more traditional parcel tracking solutions, thus avoiding too costly investments.

Petr Andrianov's scepticism towards use of blockchain technology underscores a cautious approach to innovative technologies. Cost effectiveness and operational simplicity considerations are paramount for the company now. This

perspective is particularly relevant to the research, illustrating the economic barriers to BT adoption in the logistics sector and highlighting the importance of aligning technological investments with company size and financial capabilities.

3.3.2 Analysis of Interview with Goran Gjorgievski

Unlike Petr Andrianov's more cautious approach towards blockchain adoption, Goran's point of view is notably more optimistic. Goran even wrote his master's thesis, where he proposed a working concept, which utilise Ethereum blockchain, smart contracts, and Post tokens as incentive for involved players in the "last mile delivery" of the global supply chain (Gjorgievski, 2022).
According to Goran, BT has potential benefits in addressing common logistical challenges within large-scale operations, for instance, as those of Posti Group Oyj. Goran mentioned that company process more than 300.000 parcels on the daily basis with each parcel undergoing 6-7 steps before reaching its destination, making roughly more than 2 million of operations per day. Even with modern tracking systems involved, errors and losses can appear. By leveraging blockchain's core features like data immutability, integrity and traceability, Posti Group can enhance reliability of their tracking systems.
Secure and transparent record of transactions can minimise risk of errors and lost packages, thus building trust with customers. According to Goran's perspective, the integration of blockchain technology into Posti Group's logistical operations might result in increase in operational effectiveness and customer satisfaction, despite the high initial investments and technological complications.

Goran states, that the most challenging factor during the BT adoption, is the reach for consensus among all players in the supply chain. It will be hard to convince partners to "jump on the blockchain train," because this technology is not well-known for the masses and looks too futuristic.
Thanks to the Goran's observations, the potential of blockchain technology in logistics sector has become clearer. He has a forward-thinking attitude, since

he believes, that BT could improve tracking accuracy, reduce fraud, and potentially revolutionise parcels delivery industry. Despite the numerous obstacles on the way to mass blockchain adoption, Goran underscores the importance of innovation and the willingness to accept technological advancements for long-term benefits.

3.3.3 Comparative synthesis

Both interviews show how different can be the strategies, when it comes to implementing innovative technologies. The comparison highlighted the diverse viewpoints, when company decisions depend on balancing cost, strategic advances, and technological readiness. It demonstrates the businesses difficulty when adapting new technologies: they need to consider short-term expenses versus long-term strategic benefits and the possible industry enhancement.
These viewpoints help better to understand blockchain technology potential impact, suggesting a nuanced, case-by-case adoption scenario in the delivery industry.

3.4 Comparative Analysis with Existing Models

Comparing lead organisations already functioning blockchain projects with interview responses reveals a spectrum of adoption and potential within supply chain industry. Unlike Starship Technologies and Posti Group Oyj, companies like Walmart, De Beers, FedEx, and DHL have successfully implemented blockchain technology to improve security, transparency, and efficiency across their logistical operations.
Walmart has cooperated with an IBM to be able to trace food products authenticity and safety by means of blockchain technology. De Beers' Tracr technology uses blockchain for ethical diamond sourcing, which is providing tamper-proof record from the mines in South Africa to the merchant's shop in Europe. FedEx has adopted blockchain for dispute resolution, by improving cargo visibility and customer service, demonstrating technology's versatility far beyond traditional tracking systems.

This comparison highlights blockchain's numerous logistical applications and a larger trend which is leaning toward digital transformation, driven by the industry demand for more openness, security, and efficiency in global supply chains.

4 DISCUSSION

4.1 Interprattation of findings

In this research I have explored the possible application of blockchain technology within supply chain management, focusing on its impact on parcel tracking industry and broader logistical landscape. The results obtained from existing literature and real-world case studies, coupled with empirical research, provide insights regarding the potential of blockchain to transform contemporary delivery methods. The findings also pointing out the challenges it faces for widespread adoption.

4.2 Summary of Key Findings

The case studies from global leading logistics providers like UPS and FedEx confirm, that blockchain technology has the potential to provide real-time, immutable tracking data, which can significantly improve parcel tracking accuracy and reduce loss rates. The real-world use aligns with the literature and emphasize blockchain technology’s role in supporting trust and transparency across complex supply chains.

4.3 Challenges and Limitations

Like with any other innovative technology, blockchain adoption has its negative sides. Technical challenges emerge as a primary concern. For instance,

integration with existing IT systems and scalability could bring a lot of headaches for engineers. Other factors what can impede adoption are the organisational barriers, people reluctance to change and a lack of blockchain literacy. And the finally is the regulatory uncertainty, with a clear need for established standards to guide blockchain’s use in the logistics sector.

4.4 Prospects and Areas for Improvement

To fully realize the potential of blockchain technology it is essential to make collaborative efforts to overcome existing obstacles. Future innovations in this field should concentrate on enhanced scalability and user-friendliness, to be able seamlessly integrate with already existing systems. Finally, wide-spread cooperation between all stake holders in the logistics business, is essential to facilitate broader acceptance of blockchain technology.

4.5 Contribution to the Field

This thesis contributes to both academic knowledge and practical understanding of blockchain's role in supply chain management. By bringing out the technology's benefits and challenges, the research provides a balanced view that can influence future studies and a guidance for industry practices. The hype around the blockchain technology is still high- that means money inflow and further development; therefore, this innovative technology has ability to transform logistics and supply chain management in the future. It will remain the critical area of exploration.

5 CONCLUSION

5.1 Summary of key findings

Due to ability to ensure unmatched data integration and transparency, block-chain technology has demonstrated undeniable potential to positively reshape parcel tracking solutions. Immutable nature of blockchain records offers supply chain stakeholders real-time and trustful tracking information, which leads to minimised incidence of loss, theft, and fraud.

The ability to integrate data on blockchain from Internet of Things, RFID and GPS sensors is a particularly important milestone for the development of sus-tainability and resilience of supply chain operations. This kind of co-working allows real-time monitoring of shipments, at the same time ensuring products authenticity and environmental “friendliness.”

As with any other technological innovation there are also problematic aspects, for instance, privacy and ethical concerns. The highly praised transparency in decentralised blockchains can potentially expose sensitive data to stake hold-ers, who may not be entitled for such a profound information. However, there is a workaround- hybrid blockchains and encryption methods offer a balance, between data integrity and stakeholders’ privacy.

On the way of the global blockchain adoption into supply chain management are some key barriers, like technological complexity, lack of standardisation, and resistance to change among important players. Coordinated efforts are needed to overcome these barriers, with means of education, regulatory clarity and showcasing blockchain’s value to all stakeholders in the supply chain.

Based on the empirical research, it became clear that it is necessary to build trust and collaboration between supply chain participants. Without the team-work, it will be impossible to implement successful blockchain adoption.

Blockchain has potential to make the supply chain ecosystem more efficient by creating clear control guidelines, explicit control rules, and mutual benefits. These findings demonstrate how blockchain technology can influence supply chain management. There is also the need for constant, ongoing research, development, and ethical consideration to fully realize this technology's benefits while mitigating its challenges.

5.2 Research questions answers

1.**How can blockchain technology revolutionize parcel tracking and data integrity in supply chain management, while addressing privacy and ethical considerations?**

Integrated into the modern supply chain, blockchain technology can provide robust framework for parcel tracking. This can be achieved by immutable and secure data record, available for all users simultaneously. This feature in its turn can enhance accountability and traceability, thereby reducing fraud, loss, and theft. Real-time tracking can be done by integrating IoT devices into the blockchain, thus, operational efficiency and customer satisfaction can be improved.

2.**In what ways does integrating blockchain with IoT and other technologies contribute to sustainable and resilient supply chain operations?**

Better data integrity and real-time tracking is possible by integration of Internet of Things into blockchain, these features can make supply chain more sustainable and resilient. Based on this, it is possible to precisely monitor goods and environmental conditions, reduce waste, improve product quality, and ensure ethical sourcing. Furthermore, blockchain technology can enable quick response to supply chain disruptions, which can promote adaptability and resilience.

3.**What are the key barriers to the adoption of blockchain in supply chain management, and how can they be overcome to foster stakeholder trust and collaboration?**

The main obstacles on the way to blockchain mass adoption are derived from its innovative nature. Technological complexity, lack of standardization and resistance to change are well-known culprits. These can be fixed by making blockchain simpler to use for end users, develop universal industry standards and promote innovative ecosystem. Blockchain user benefits can be demonstrated by means of educational initiatives, pilot projects and shared best practices. All these can build trust among stakeholders and encourage collaboration across the global supply chain.

5.3 Ideas for future research

Scalability solutions research is the first idea, what comes to my mind. It is important to investigate how blockchain solutions can handle the vast amounts of data, which is generated in the global supply chains. Future researchers could explore off-chain transactions, new consensus mechanisms and blockchain sharding techniques to make scalability and performance more efficient, while maintaining security and decentralization on desired levels.

Regulatory frameworks and standardization are another important area for the future researchers. Blockchain technology is in constant developing mode and there is a need for regulatory clarity and standardisations between different jurisdictions. The development of international standards for blockchain in supply chain management can be also explored in the future studies, having emphasis on legal, ethical and privacy concerns.

Human factors and organizational change. This is another area ready for further exploration because it is important to understand, how such an innovative technology like blockchain can impact workforce skills, job roles and organizational structures.

Future impact of quantum computing. The recent progress of quantum computing poses potential security risks to blockchain technologies. Future research could concentrate on the implications of quantum computing on blockchain security, considering supply chain applications, and develop quantum-resistant cryptographic algorithms.

5.4 Final thoughts

In the final reflections of this thesis, I must admit, that blockchain technology has the potential to positively influence the supply chain landscape. Research has shown blockchain potential to improve transparency, efficiency, and security of the modern supply chains, also it highlighted the critical ethical considerations and barriers on the way to mass adoption.

The blockchain collaboration with emerging technologies like Internet of Things, promise a future where supply chain operations could be more resilient, sustainable, and responsive to global challenges. However, to be able to reach visionary goals, the collaboration between industry leaders and policy-makers is paramount.

We are on the verge of the technological revolution, and it is upon us to prioritise integrity and sustainability, to create the pathway for future innovation.

The exploration of blockchain technology in supply chains is not yet complete, it is just the beginning of a broader discourse on leveraging technology for the advanced digital future.

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APPENDIX 1. Petr Andrianov interview questions

Can you describe the core operations of your startup, specifically focusing on the use of wheeled robots for grocery delivery? How do these wheeled robots integrate into the local supply chain for groceries?

What kind of parcel tracking system is currently in use for tracking the deliveries made by your wheeled robots? How do you ensure the accuracy and reliability of your tracking system?
What kind of sensors are you using now to track robots while they are moving around the city? GPS, cameras?

What is your level of familiarity with blockchain technology in the context of supply chain management? From your perspective, what are the key benefits and drawbacks of integrating blockchain technology into supply chain systems?

In your opinion, how could blockchain technology enhance the parcel tracking capabilities of your delivery system? Can you envision any specific blockchain applications that would be particularly beneficial for your business model?

What challenges do you anticipate, if company decides to integrate blockchain technology into your current delivery and tracking system? Are there any technical or operational limitations that you think might hinder the adoption of blockchain in your operations?

How do you think blockchain technology could impact the efficiency and transparency of your delivery operations? Could blockchain provide any significant improvements over your current system in terms of customer satisfaction or operational efficiency?
Are there any plans or considerations within your startup to implement blockchain technology in the future? How do you see blockchain technology evolving in the context of robotic delivery services?

Based on your experience, what advice would you give to researchers exploring the use of blockchain in supply chain management and parcel tracking? Are there any other technologies or innovations that you believe should be considered alongside blockchain in this field?

APPENDIX 2. Goran Gjorgievski interview questions

I have noticed that a lot of packages are missing or coming to the customers in different batches. Could you elaborate on how your current parcel tracking system addresses these challenges, and where there might be room for improvement?

Based on our operations and the technological landscape, how do you see blockchain fitting into Posti parcel tracking solutions? I am particularly interested in how it might mesh with the systems you are currently using.

From a technical standpoint, considering Posti existing infrastructure, what do you see as the main hurdles and potential wins in integrating blockchain into your logistics operations?

In the context of Posti daily operations and the challenges we face, how do you believe blockchain could potentially revolutionize Posti parcel tracking and delivery reliability?

Given your expertise and understanding of Posti operations, are there any concerns or limitations you foresee with integrating blockchain into your existing parcel tracking system?

Have you seen any moves towards blockchain in logistics industry that caught your eye, especially from competitors or peers? What outcomes have they reported?

From your vantage point in the industry, how do you foresee the evolution of logistics management with blockchain and other emerging technologies?

Considering company's infrastructure and strategic direction, what investments do you think are critical for embracing a blockchain-based tracking system?

Based on your interactions and customer feedback, how do you think your stakeholders would react to the implementation of blockchain in parcel tracking system?

From an operational and financial perspective, how do you balance the costs and benefits of transitioning to a blockchain system for parcel tracking efficiency?