ASSOCIAÇÃO DE POLITÉCNICOS DO NORTE **(APNOR)**
INSTITUTO POLITÉCNICO DE BRAGANÇA

Logistics Models Smart Contracting Approach Based on Blockchain Technologies: a roadmap to Armenian Logistics Companies

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Final Dissertation submitted to *Instituto Politécnico de Bragança*

To obtain the Master Degree in Management, Specialisation in Business Management

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***Bragança*, June, 2025**

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Abstract

The objective of this study is to explore the applicability and potential of blockchain technology and smart contracts within Armenia’s logistics environment by aligning leading international practices with local systemic challenges. A transition roadmap tailored for a smooth adaptation has been proposed. The research was conducted using a comparative-integrative methodology, combining the analysis of professional literature, expert interviews, and benchmarking of existing advanced practices. The study attempts to align traditional and blockchain-based logistics models, taking into account the rigid traditions of the local business culture, the urban-economic context, the logical direction and pace of potential legislative alignment.

Based on the findings, an 11-step innovative model has been proposed, which enables a complete revision of the freight transportation process - from cargo request to final delivery. The model includes automated data exchange, smart contract-based transactions, and transparent oversight, significantly reducing administrative burdens and the likelihood of human error.

The study also identifies key barriers to blockchain adoption among Armenian logistics companies, including low sectoral awareness, the absence of institutional platforms, and legal uncertainties. In this context, a 6-step roadmap is proposed to guide companies through phased digitalization and the integration of innovative technologies.

This thesis has theoretical, practical, and public relevance. It can serve as a guide for both private sector management and the development of public strategic policy. Furthermore, it outlines directions for future research, including pilot implementations, in-depth legal framework analysis, and technological platform adjustments in collaboration with developers.

Keywords: smart contracts, logistics, blockchain, supply chain, IoT, transparency.

Resumo

O objetivo deste estudo é explorar a aplicabilidade e o potencial da tecnologia blockchain e dos contratos inteligentes no ambiente logístico da Arménia, alinhando as melhores práticas internacionais aos desafios sistémicos locais. Foi proposto um roteiro de transição adaptado para uma adoção gradual e eficaz. A investigação foi conduzida com base numa metodologia comparativa-integrativa, combinando a análise de literatura especializada, entrevistas com especialistas e a comparação de práticas avançadas existentes. O estudo procurou articular modelos logísticos tradicionais e baseados em blockchain, considerando as tradições enraizadas da cultura empresarial local, o contexto socioeconómico urbano, bem como a direção e o ritmo prováveis de adaptação legislativa.

Com base nos resultados, foi proposto um modelo inovador de 11 etapas, que permite uma reavaliação completa do processo de transporte de mercadorias - desde o pedido inicial até à entrega final. O modelo prevê a troca automatizada de dados, transações reguladas por contratos inteligentes e uma supervisão transparente, reduzindo significativamente a carga administrativa e a probabilidade de erro humano.

No âmbito da pesquisa, também foram identificados os principais obstáculos à adoção do blockchain pelas empresas de logística arménias, incluindo o baixo nível de conhecimento setorial, a ausência de plataformas institucionais e a incerteza quanto à regulamentação legal. Neste contexto, foi sugerido um roteiro de 6 etapas que permite às empresas implementar gradualmente a digitalização e a integração de tecnologias inovadoras.

A dissertação apresenta relevância teórica, prática e pública. Pode servir como guia tanto para a gestão do setor privado quanto para a formulação de políticas estratégicas públicas. Ao mesmo tempo, indica direções para futuras investigações, incluindo projetos-piloto, análises aprofundadas do enquadramento jurídico e o aperfeiçoamento das plataformas tecnológicas em colaboração com programadores.

Palavras-chave: contratos inteligentes, logística, blockchain, cadeia de abastecimento, IoT, transparência.

Աբստրակտ

Այս ուսումնասիրության նպատակն է բացահայտել բլոկչեյն տեխնոլոգիայի և խելացի պայմանագրերի կիրառելիությունն ու ներուժը Հայաստանի լոգիստիկ միջավայրում՝ համադրելով միջազգային առաջատար փորձը տեղական համակարգային խնդիրների հետ. առաջարկվել է անցնցում անցման համար հարմարեցված ճանապարհային քարտեզ։ Հետազոտությունն իրականացվել է համեմատական-համադրական մեթոդաբանությամբ. մասնագիտական գրականության, փորձագիտական հարցազրույցների և գոյություն ունեցող առաջավոր փորձերի վերլուծության և համեմատության միջոցով կատարվել է ավանդական և բլոկչեյն հիմքով մոդելների համադրման փորձ՝ հաշվի առնելով տեղային գործարար մշակույթի կարծր ավանդույթները, քաղաքատնտեսական միջավայրը, օրենսդրական համապատասխանեցումների հնարավոր տրամաբանական միտվածությունը և արագությունները։

Արդյունքների հիման վրա առաջարկվել է 11 քայլանոց նորարարական մոդել՝ որը թույլ է տալիս ամբողջությամբ վերանայել բեռնափոխադրումների գործընթացը՝ սկսած բեռի հարցումից մինչև վերջնական առաքում։ Մոդելում նախատեսվում են ավտոմատացված տվյալների փոխանակում, սմարթ կոնտրակտներով պայմանավորված գործարքներ և թափանցիկ վերահսկողություն, որոնք զգալիորեն նվազեցնում են վարչարարական բեռը և մարդկային սխալների հավանականությունը։

Հետազոտության շրջանակներում նաև վերհանվել են բլոկչեյնի ներդրման խոչընդոտները Հայաստանի լոգիստիկ ընկերություններում՝ ներառյալ ոլորտային թերի իրազեկվածությունը, ինստիտուցիոնալ հարթակների բացակայությունը, ինչպես նաև իրավական կարգավորումների անորոշությունը։ Այս համատեքստում առաջարկվել է 6 քայլանոց ճանապարհային քարտեզ, ըստ որի՝ ընկերությունները կարող են փուլ առ փուլ կատարել թվայնացում և նորարարական տեխնոլոգիաների ինտեգրում։

Թեզն ունի տեսական, գործնական և հանրային կիրառելիություն։ Այն կարող է ծառայել որպես ուղեցույց՝ ինչպես մասնավոր հատվածի կառավարման, այնպես էլ պետական ռազմավարական քաղաքականության մշակման համար։ Միաժամանակ, այն մատնանշում է հետագա հետազոտությունների ուղղություններ՝ ներառյալ պիլոտային փորձարկումներ, իրավական միջավայրի խորացված վերլուծություն և տեխնոլոգիական հարթակի ճշգրտում՝ ծրագրավորողների հետ համագործակցությամբ։

Հիմնաբառեր՝ խելացի պայմանագրեր, լոգիստիկա, բլոկչեյն, մատակարարման շղթա, IoT, թափանցիկություն։

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Introduction

Logistics, has been a subject of human interest since the dawn of civilization, and as a formal science it emerged in the 17th and 18th centuries, mainly in a military context. During and after the Second World War, and especially from the 1960s until today (Magee, 1968), it has been developing as an interdisciplinary discipline and science. The issue of logistics has been studied by many researchers around the world, including Portuguese (Correia & Mendes, 2024) and Armenian specialists (Chibukhchyan, 2006). Over decades, the topic of logistics has undergone dialectical development, expanding not only in depth, but also by encompassing new areas and dimensions of study - financial, economic, psychological, aesthetic, legal, technological, and more. In recent years, the global logistics industry has been undergoing a profound transformation thanks to digital technologies. Blockchain, once primarily associated with cryptocurrencies, has become a disruptive force in supply chain management, offering traceability, improved transparency, automation, and trust. In this context, smart contracts – self- executing applications based on blockchain technology – have shown the potential to automate and secure operational processes.

The logistics industry in Armenia plays a strategic role, but faces numerous structural and operational challenges, including paper-based processes, fragmented systems, limited trust, and not enough adoption of digital innovations. With these issues in mind, our research examines how our blockchain-based smart contract model can be adapted to the Armenian reality through a practical, structured roadmap that supports the transition of Armenian logistics companies to the digital age.

The problem statement highlights that the introduction of modern logistics management makes it possible to accelerate capital turnover, reduce the costs of production and product distribution, and strengthen the company's position in the market (Chibukhchyan, 2006). While the world is increasingly recognizing the potential of blockchain in global logistics, the Armenian reality lacks a localized, practical model for its integration. Existing studies on the topic either ignore the Armenian context or remain overly theoretical.

Moreover, Armenian logistics companies often do not even have digital infrastructures, and they hesitate due to a lack of familiarity with decentralized technologies, as well as legal-legislative uncertainty.

This research addresses a critical gap between theory and practice by proposing a blockchain-based smart contract roadmap for end-to-end freight transportation, tailored to Armenian logistics companies and built on real-world feedback and data collected through expert interviews and local case studies.

The research objectives are centered around a contractual approach to the logistics model, which is based on smart contracts and blockchain technology.

The research questions are:

A. What are the current global practices for implementing blockchain and smart contracts in logistics, and which elements are applicable in the Armenian context?

B. What are the digital and operational gaps in Armenian logistics companies that hinder the implementation of blockchain technologies?

C. What does a blockchain-based model look like considering the activities of Armenian companies?

D. What are the main stages that companies in the logistics sector in Armenia should go through when making a decision to integrate blockchain?

E. What role do institutional support, workforce readiness, and technological capabilities play in the successful implementation of such models?

Accordingly, the main objectives of the research are:

a) To scientifically substantiate the role of blockchain technologies, smart contracts, IoT systems in logistics,

b) To identify the applicability of blockchain and smart contracts in global logistics systems,

c) To investigate the current operational and digital maturity of Armenian logistics companies,

d) To identify the problems existing in the logistics system in Armenia, the main obstacles and driving forces for the implementation of blockchain,

e) To develop a blockchain-based model based on Armenian logistics experience,

f) To develop a practical roadmap for the implementation of this model in Armenian logistics operations.

The scope and limitations of this research are defined as follows:

This research focuses specifically on logistics companies operating in the Republic of Armenia. While examples and benchmarks are taken from international applications, the main goal remains to develop a roadmap that is adaptable to Armenia's unique regulatory, infrastructural, and economic conditions. The research is limited by the availability of real-time operational data from local companies, culture shock, and the legal status of blockchain-based contracts in Armenia. The proposed model is subject to development by developers and technical issues may arise during the process.

The significance of this study lies in its provision of an opportunity to consider the practical application of a newly developing toolkit in the Armenian logistics sector, both theoretically and with a unified scientific approach. Combining global best practices with local insights, this thesis creates a practical framework for the implementation of blockchain and smart contract models in the logistics sector of Armenia. The developed roadmap aims to assist decision-makers, business leaders, and technology consultants in shaping a seamless, secure, transparent, and efficient digital logistics environment in Armenia. This work serves not only as a theoretical knowledge base but also as a practical tool that can be beneficial for managers in other enterprises. The obtained results can be used to develop strategies and measures that will contribute to the successful implementation of the digital leadership ecosystem and help overcome potential difficulties.

This thesis is structured in six main chapters, each of which contributes to the development of a blockchain-based smart contract roadmap for Armenian logistics companies.

Introduction presents the background of the thesis, the formulation of the problem, the research questions, the objectives, and the methodology.

Chapter 1 examines the methodology of this thesis.

Chapter 2 examines the historical development of blockchain technology and its theoretical foundations in the logistics sector.

Chapter 3 examines the role of smart contracts in automating and increasing the efficiency of logistics processes.

Chapter 4 analyses global logistics in the world, in particular transport logistics; revealing the role and main applications of IOT.

Chapter 5 assesses the current state of the Armenian logistics sector, including its digital readiness and operational challenges, and proposes a localized roadmap for the implementation of blockchain-based smart contract models in Armenian logistics companies.

Conclusion section includes the logical conclusions of this master's thesis.

The work ends with a ***list of references*** and ***appendices***.

1. Research Methodology

1.1. The Basic Principle, Approach and Methods of the Study

This study has been conducted using a methodology grounded in a deductive-rationalist ideal combined with inductive reasoning, and guided by the principles of neutrality, empirical observation, and scientific justification. The methodological approach includes the following components: a) data collection, b) data analysis, c) comparison of collected data both internally and against advanced international benchmarks, d) correlation of empirical and theoretical knowledge, e) calculation of the impact of geopolitical realities, f) accounting for cultural specificity, g) logical conclusion and possible effective map proposal. No statistical testing or econometric modeling has been conducted, as the research is theoretical and qualitative in nature.

1.2. Objective of the Study and Research Questions

The aim of this study is to develop a roadmap for blockchain-based smart contracts that will be tailored to the needs and challenges of Armenian logistics companies. Given the qualitative nature of the study and its exploratory approach, no formal statistical hypotheses are tested, the model has not yet been implemented, and specific results cannot be legitimately drawn. However, the study is guided by the following assumptions:

- Blockchain and smart contracts can be effectively adapted to Armenian logistics processes, given appropriate institutional and technical support.
- Armenian logistics companies face certain structural and digital gaps that hinder innovation.
- A localized roadmap can facilitate the implementation of a blockchain-based model and mitigate resistance to change.

1.3. Description of Data Collection

Data collection was based on two main tools:

- Literature review of academic sources, white papers and reports on the use of blockchain in logistics and supply chain management.
- Interviews with Armenian logistics professionals, including selected local company executives and operational staff.

The interviews were conducted in March-April 2025, via WhatsApp or in person, depending on the availability of the respondents. The questions focused on current business models (to visually describe the traditional map image), the challenges they face, knowledge and perception of innovative technologies, in particular blockchain, readiness for digital transformation and expectations from automated contracting systems.

1.4. Description of Data Analysis

This study employs the method of qualitative content analysis to interpret the interview data and identify common patterns among the responses.

In addition, in our study:

- The model formed as a result of a comparative analysis of global experience is as closely aligned as possible with the Armenian logistics environment,
- A comparative mapping was carried out to clarify the differences and opportunities between the proposed model and traditional logistics practices,
- Through comparative analysis, the key components of successful international practices were selected as a guide for the development of the local system,
- A roadmap was developed based on a phased structure that ensures logical sequence and practical feasibility.

1.5. Population *vs.* Sample

The population consists of logistics companies operating in Armenia, specifically those providing freight forwarding, warehousing, and transportation services.

The sample included 10 Armenian logistics companies, which were selected through purposive sampling based on their size, level of activity, and willingness to participate in interviews. Some of the companies that reluctantly agreed to be interviewed wished to remain anonymous. The sample size was not statistically calculated, as the study aimed at depth and contextual relevance, not statistical generalization.

2. The History and Modern Application of Blockchain

Just as the Internet has transformed communication capabilities, blockchain has the potential to change- and is already visibly transforming - the entire business world and the way it works today. The industry is known to be at the forefront of academia regarding disruptive technologies such as blockchain and smart contracts (Bauk, Blockchain conceptual framework in shipping and port management, 2022). One of the main objectives of this thesis is to explore the potential benefits that justify the efficiency and inevitable integration of blockchain technology in logistics; therefore, the faster and more systematic this integration takes place, the greater the overall benefits for the logistics sector. In this section, we will provide a comprehensive and detailed explanation of the technologies that have made blockchain possible, starting with an explanation of some critical concepts behind the definition of blockchain and the current challenges facing blockchain technology in logistics.

2.1. The Origins of Blockchain Technology

The concept of blockchain technology evolved through a series of technological advancements in cryptography, networking, and decentralization. By the mid-1990s, Internet services were primarily built using a "client-server" model. Servers owned by early "dotcom" companies would run one or more computer programs, hosting websites and providing a variety of applications that Internet users could access through their clients. So, the information typically flows in a single direction: from server to client, like a one-way supply chain in logistics. The idea was that the server could share its resources, but the clients could only use them and couldn't share theirs with other clients or the server itself. Meanwhile, a parallel revolution was already underway in the world of cryptography, laying the groundwork for more decentralized systems.

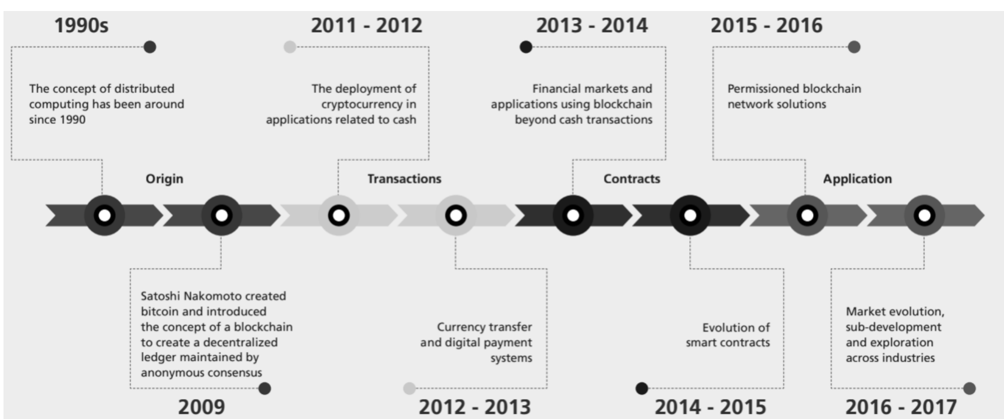

Figure 1. Blockchain history

Source: DHL & Accenture, 2018

2.2. The Emergence of Public-Private Key Cryptography

In 1976, two cryptographers from Stanford University, Whitfield Diffie and Marty Hellman, created the concept of public-private key cryptography, which solved the need for secure key distribution, which was one of the fundamental problems of cryptography (Diffie & Hellman, 1976). . At the same time, they provided the theoretical basis for authenticated digital signatures. In 1978, building on the groundbreaking work of Diffie and Hellman, MIT cryptographers Ron Rivest, Adi Shamir, and Len Adleman developed the RSA algorithm, a public-private key encryption method based on the mathematical complexity of simple factorization (Rivest, Shamir, & Adleman, 1978). This algorithm allows users to share public keys widely while ensuring that private keys remain secure, enabling encrypted communication and resisting forged digital signatures. Using RSA, sensitive messages can be encrypted with the recipient's public key and signed with the sender's private key, ensuring authenticity and confidentiality. This innovation paved the way for new applications such as electronic cash, digital contracts, and pseudonymous reputation systems, revolutionizing secure communication and encryption technologies.

These groundbreaking innovations became a critical component for secure online communication, laying the foundation for the emergence of Peer-to-Peer (P2P) networks, a milestone in decentralized technology, and solved the above problem. This later became the basis for the use of blockchain in logistics.

2.3. The Emergence of Peer-to-Peer Networks

As Rüdiger Schollmeier explains in his article: "*A distributed network architecture may be called a Peer-to-Peer (P-to-P, P2P, …) network, if the participants share a part of their own hardware resources (processing power, storage capacity, network link capacity, printers,...). These shared resources are necessary to provide the Service and content offered by the network (e.g. file sharing or shared workspaces for collaboration). They are accessible by other peers directly, without passing intermediary entities. The participants of such a network are thus resource (Service and content) providers as well as resource (Service and content) requestors (Servent-concept)*." (Schollmeier, 2001, pp. 101-102)

Later, P2P gained widespread recognition because of the Napster brand. With Napster's software, anyone could download music files from other users (acting like a client) and share their music files with others (acting like a server). Napster connected millions of computers worldwide using this approach, creating a vast, unparalleled music library. Napster's popularity was short-lived due to its reliance on a centralized index of available music, the backbone of its peer-to-peer network. This centralization led to copyright infringement lawsuits, forcing Napster to remove protected music from its index. As a result, its scalability decreased, and users moved to other platforms. This led to new decentralized peer-to-peer networks such as Gnutella (Ripeanu, 2001) and BitTorrent (Cohen, 2003), which enabled file sharing without a central authority. Unlike Napster, the logistical method worked here; these relied on fully decentralized architectures that distributed the responsibility for file sharing among their peers, avoiding the legal vulnerabilities of centralized systems.

Developments in peer-to-peer networks, combined with cryptographic innovations, are preparing fertile ground for the creation of blockchain technology. During that time, logistics also developed.

2.4. The Birth of Blockchain

During those years, many other attempts were made with models that now seem "simple." However, technological development gained such momentum that many began to think about creating new, more widely applicable tools and matching them to the existing framework. These tools aim to reduce dependence on governments and be less controlled by banks. In October 2008, an anonymous individual or group using the name Satoshi Nakamoto solved this problem by combining digital signatures, public-private key cryptography, and peer-to-peer technologies to develop a revolutionary distributed database that later became known as the *blockchain*.

This innovation allowed Nakamoto to create a decentralized digital currency that operated independently, eliminating the need for a centralized intermediary. In his nine-page article *"Bitcoin. Entitled Peer-to-Peer Electronic Cash System"* (Nakamoto, 2008) Satoshi Nakamoto presents the concept of a technology built on blocks linked together to form a chain that ensures the integrity and transparency of transactions. This innovative system, now known as blockchain, relies on cryptographic proofs rather than trust, allowing participants to engage in secure, decentralized peer-to-peer transactions without needing a centralized intermediary.

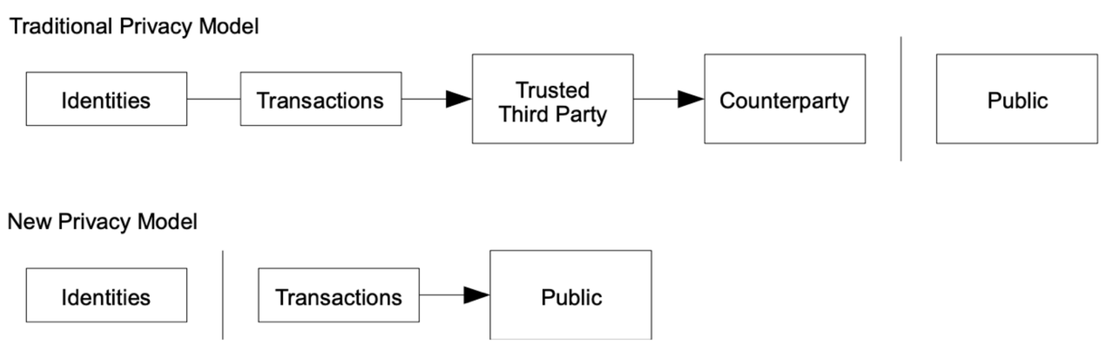

Figure 2. The traditional banking model and Blockchain New Model

Source: Nakamoto, 2008

Nakamoto explains how each block contains a collection of authenticated transactions and is cryptographically linked to the previous block, forming an immutable chain, which is very similar to a logistics closed circle. The traditional banking model achieves privacy by limiting access to information to the parties involved and the trusted third party. The necessity to announce all transactions publicly precludes this method, but privacy can still be maintained by breaking the flow of information in another place: by keeping public keys anonymous. The public can see that someone is sending an amount to someone else without information linking the transaction to anyone. This is like the level of information released by stock exchanges, where the time and size of individual trades, the "tape", is made public, but without telling who the parties were (Nakamoto, 2008).

This structure prevents counterfeiting and solves the double-spending problem plaguing previous attempts at digital currencies. Combining public-private key cryptography, digital signatures, and a proof-of-work mechanism, Nakamoto's blockchain technology paved the way for the revolutionary digital currency system - Bitcoin.

Since its discovery and use in 2009, Bitcoin has become one of the largest payment systems in the world. Still, its technical foundations remain as mysterious to many as its founding and founder. As *blockchain* experts, the French legal scholar Primavera De Filippi and the American law professor Aaron Wright explain in their book “Blockchain and the Law: The Rule of Code” (De Filippi & Wright, 2018), one way to understand Bitcoin functions is to compare it with e-mail, which is also one of the main tools in logistics. An e-mail address allows us to receive electronic messages from anyone with access to the Internet and an e-mail address. You can even create an email address without using your accurate information, such as name, surname, or birth data; you can use pseudonyms and act as an email address for just receiving and sending messages. Of course, you can activate a third-party authenticator to manage email and keep it safe from attacks. However, the underlying protocol for emailing (sending or receiving) is still free, open, and can work without having to ask permission from any other device. To enter an email inbox, you must create a personal password, allowing people to control their accounts. Bitcoin works much like email. It is an open and interoperable technology not regulated by any central authority. Bitcoin uses a public-private key system, allowing users to create accounts without institutional approval. With this account, users can send and receive Bitcoin worldwide in minutes by transacting with their private key. After a transaction, members of the Bitcoin network verify its validity and update the balances of the relevant accounts accordingly. Network users confirm that Bitcoin, with security risks, such as attacks on alternative chains, is being investigated.

The researcher also discusses the scenario of an attacker trying to generate an alternate chain faster than the honest chain (with honest nodes). The conclusion is that even if an attacker succeeds, this doesn’t mean that the system is open to arbitrary changes, like creating value from air or taking money that does not belong to the attacker. An attacker can only try to change one of their transactions to take back money they recently spent (Nakamoto, 2008).

Bitcoin transactions aren’t free, because the Bitcoin protocol allows the leaving of a “transaction fee” for the miners (Kroll et al., 2013), like a transaction margin in the logistics industry.

How Does It Work?

First, Bitcoin transaction fees are not mandatory, but without them, your transaction may take a long time to be confirmed, so in practice, almost all transactions include a fee to ensure faster processing. Transaction fees are voluntary; the user can pay the miners an additional fee. However, the Bitcoin network operates on a priority basis, and miners prefer to process transactions with higher fees *first*. If a transaction has no or very low fees, it may remain unconfirmed for a long time or may not even be included in any blocks. So, if the Bitcoin network is not congested, a transaction without a fee can still be confirmed, but it can take a long time, and if the network is busy, transactions with higher fees will be processed first, while transactions with no or low fees may be left pending. Also, we need to mention that the fee depends on the network congestion. Sometimes, it can be as low as 0.0001 BTC (approx. $5-$10), but it can increase to $20 or more during peak times. The fee is also based on the transaction size in bytes, not the number of Bitcoins transferred.

While Bitcoin was the first and most well-known use case of blockchain, its limitations highlighted the potential of blockchain applications beyond digital currencies, including logistics.

2.5. Ethereum

Interest in Bitcoin grew, and traditional businesses and venture capitalists like Dell and Microsoft explored Bitcoin as a payment option (Smith, 2014; Marino, 2015). However, the more people looked at Bitcoin, its limitations became apparent. Bitcoin has excelled as a platform for facilitating the exchange of digital currency. Blockchain technology has evolved in the cryptocurrency space and beyond, finding applications in logistics, healthcare, and supply chain management. It all started with the slow Bitcoin network: it could only reach consensus and confirm transactions every ten minutes, raising questions about how much information the blockchain could hold. The Bitcoin network was running slow because Bitcoin's decentralized structure made it difficult to update and improve its protocol. Because the network had no formal governance at that time, it relied only on the efforts of a small group of programmers who slowly reviewed and fixed software bugs. As Bitcoin's limitations became more apparent, the need for a more flexible and scalable blockchain system emerged. Developers and researchers began exploring ways to extend blockchain technology beyond financial transactions.

Generally, because blockchain is a data storage system, the technology can store more than just Bitcoin transaction data. Blockchains can also store or reference other types of information, including small programs that technological professionals often call *smart contracts,* which are the primary tool for logistics in blockchain. One of the most important innovations in this regard was Ethereum, introduced by Vitalik Buterin in 2013 and launched in 2015 (Buterin, 2014; Tual, 2015). Unlike Bitcoin, which was designed primarily for peer-to-peer digital currency transfers, Ethereum was created as a programmable blockchain platform, enabling decentralized applications (DApps) and smart contracts to be implemented without intermediaries. Ethereum also implements a programming language called Solidity (Solidity, URL), which makes it possible to write smart contracts and deploy decentralized applications for anyone.

Another key difference between Bitcoin and Ethereum is block time. The Ethereum blockchain is updated roughly - every twelve seconds compared to Bitcoin’s ten-minute interval. Significantly improving transaction speed and network efficiency.

Much of daily life depends on the logistics, including the supply chain, and its transparent, high-quality, and safe products. Thus, there was an urgent need for an efficient and reliable solution to increase logistics control.

Since its launch, Ethereum has become the foundation of decentralized finance (DeFi), non-fungible tokens (NFT), and enterprise blockchain solutions, transforming many industries. It has made Ethereum a key player in the evolution of blockchain beyond cryptocurrency.

2.6. Blockchain Applications Beyond Cryptocurrency

Businesses, and in some cases entire industries, have been built on the principle of trust for centuries. However, trust in business has been undermined and transformed by blockchain technology. Despite its short history (see Figure 1), blockchain is rapidly advancing and is currently featured on corporate agendas and in the media. Interestingly, the term "blockchain" itself was not used at the time, not even by Satoshi Nakamoto; instead, early developers called it "block chain" in internal communications as a shorthand to describe the technology. Now, it has taken over the world, as evidenced by the exponentially growing numbers. The size of the blockchain market has seen explosive growth in recent years. It will increase from $28.93 billion in 2024 to $49.18 billion in 2025, a compound annual growth rate (CAGR) of 70.0% (The Business Research Company, 2024).

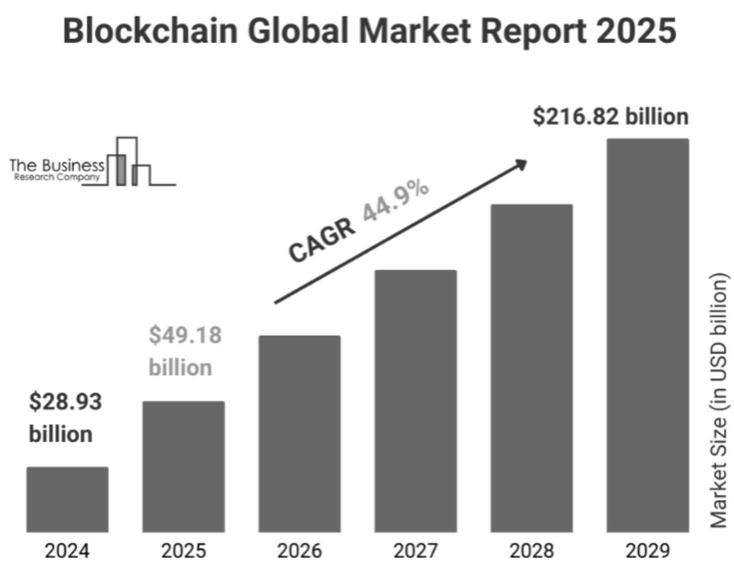

Figure 3. Global Blockchain Market CAGR 2024-2029

Source: The Business Research Company, 2024

Blockchain already has a significant impact on everyday life. While Bitcoin and Ethereum demonstrated the reach and capabilities of blockchain in the digital currency and software industries, their influence has extended beyond cryptocurrencies. The majority of supply chain-related literature on blockchain technology shows the development of theoretical frameworks and models (Helo & Hao, 2019; Karumanchi et al., 2019;

Madumidha et al., 2019; Nakasumi, 2017), examines the opportunities, obstacles, and drivers (Biswas & Gupta, 2019; Frizzo-Barker et al., 2020; Lohmer & Lasch, 2020; Petersen et al., 2018; Queiroz & Fosso Wamba, 2019; Zhao, et al., 2019), and suggests possible applications in specific supply chain segments or types (Fu et al., 2018;); Mandolla et. al., 2019; Ahmad, et al., 2020).

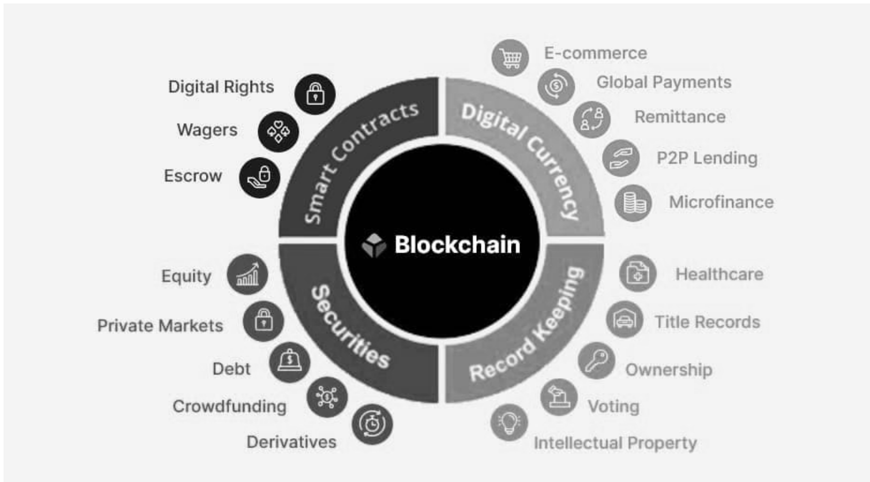

Figure 4. Blockchain applications (from ACI Worldwide)

Source: Cyber-Security Research Innovation Lab, URL

To achieve their organizational objectives by connecting their supply chains with digital transformation, numerous businesses have embraced the use of cutting-edge technologies like blockchain technology (BCT) in business-to-business (B2B) operations (Zhang & Liu, 2022). Blockchain is a game-changer in data management. It speeds up processes, improves efficiency, and introduces automation through smart contracts that only trigger when written conditions are met. This technology enhances security, fosters trust, and opens new avenues for innovation and growth across industries.

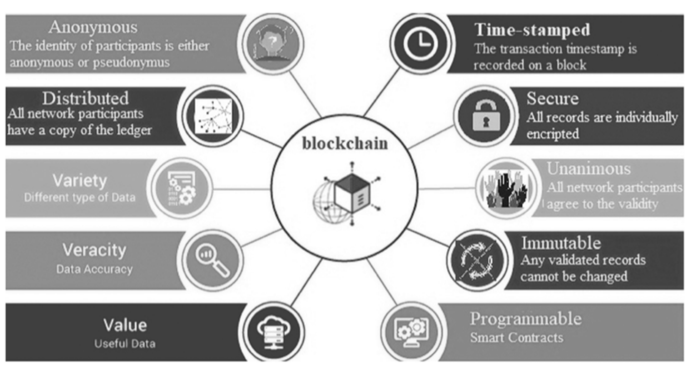

Figure 5. Features of Blockchain technology

Source:Aleksieva et al.,2023

This technology has already penetrated several fields, and many scholars and online platforms have discussed these fields (IDC, 2024; Metaschool, 2024; Acropolium, 2024; Webisoft, 2025; Built In, 2024).

There are many examples of using blockchain methods for different fields, but we will focus on a few of them, such as:

- ***Healthcare***: In healthcare, blockchain enables the secure storage and sharing of all patient records in one place while maintaining data integrity, saving lives by making it possible to avoid certain medications based on a patient's entire treatment process or past medical history. Examples of such projects include MedRec (MIT Media Lab, URL), Patientory (Patientory, URL), Medibloc (MediBloc, URL), and others.
- ***Energy and Utilities:*** The energy and utilities sector is undergoing a blockchain-based transformation, prioritizing private-to-private energy purchases and increasing grid efficiency. Blockchain, for example, allows solar panel owners to trade (Tummalapenta & Saravanan, 2024, p. 2) excess energy directly with their neighbors instead of going through utilities. Other capabilities include automating energy distribution, managing renewable energy certificates, and executing carbon credit transactions through blockchain smart contracts. And because there are too many "users" here, and they are at different distances, producing different powers, without logistics, the system will not be effective, if not unreal.
- ***Government:*** Blockchain technology is gaining popularity in the government sector to improve efficiency, security, and transparency. For example, Estonia (PwC, URL) was the first Nation-State in the world to deploy blockchain technology in the production system, and the country also uses blockchain technology for e-government. The government uses blockchain technology to secure public documents, including health and property deeds. This improves the efficiency of public services, reduces fraud, and ensures data integrity. In the future, countries that have embarked on the development path will use this model, and the share of technology in the governance system will be more significant.
- ***Agricultural and food:*** Using blockchain in the agriculture and food sectors, stakeholders can quickly track and recall contaminated food products, reducing the health risks and costs associated with foodborne illness outbreaks. A notable example is Walmart, which chose to track leafy greens for its blockchain experiment, significantly reducing the time it took to identify sources of contamination (Sharma & Kumar, 2021). This, in turn, shows that without a logistics approach based on blockchain technology, it will be impossible to meet the disproportionately growing food and health needs of different parts of the planet, harmonizing and mitigating them as much as possible.
- ***Logistics and Supply Chain:*** Using blockchain in logistics and supply chain has greatly simplified and accelerated not only the exchange of goods, but also quality management and document flow control. For example, major companies such as DHL, Maersk, and FedEx use blockchain technology to truck shipments in real-time and manage their process from production to delivery to the consumer without delays and fraud.

Only the abovementioned are enough to show that blockchain-based technologies are in demand in all areas of modern life. The current problem is their more effective and unhindered application, conditioned by the legal systems of states, national characteristics, and traditional stereotypes of people.

2.7. Current challenges facing blockchain technology in logistics, including supply chain

Blockchain is reimagining various industries by introducing transparency, efficiency and security. It certainly has its advantages and disadvantages depending on the industry, but our work focuses on logistics and blockchain's significant impact in this area. One thing is clear: blockchain can impact the logistics business at every conceivable level, especially the supply chain. This is because global supply chains are complex and involve multiple stakeholders, conflicting interests, and third-party intermediaries. These are the problems that blockchain solves. In logistics, blockchain can increase operational efficiency and develop new business models. By establishing an information trail and guaranteeing security and data immutability, blockchain has surfaced as a viable alternative for implementing traceability (Agrawal et al., 2021). Blockchain-based traceability makes secure information interchange, operational and product quality monitoring and control, real-time data collecting, supply chain transparency, and visibility possible (Azzi et al., 2019).

Employees of Deloitte Consulting LLP (Henry et al., 2023) mentioned that blockchain records the collected data points as immutable records, through which managers can track and identify specific points of failure and plan for the rerouting of necessary goods. Many logistics companies, like FedEx, have developed a system that allows for the real-time tracking and monitoring of shipments. With the help of this blockchain-based system, which provides a secure, tamper-proof, and decentralized database, workers can record every step of the shipment process from the point of production to the final delivery destination. The system used smart contracts to inform each side (shipper, carrier, or receiver) about every transfer of ownership or possession of goods between the same sides. So, everyone in the circle is assured of the current status and the shipment warehouse. This point is about trust, and as was genuinely mentioned in the Deloitte article (Henry et al., 2023), with the help of this technology, it is not necessary for all members to trust or even know each other. If a dispute arises due to any stakeholder in the logistics model, the smart contract can automatically trigger a resolution process, such as returning the shipment to the original shipper (Robitzski, 2018).

Despite all this, there are still several problems that do not make the application of technology in logistics complete (Turyan & Harutyunyan, 2025), such as:

- ***High Initial Costs:*** One problem, for example, is that implementing Blockchain technology requires significant investments in hardware, software, infrastructure and employee training. This can be particularly challenging for small and medium-sized logistics companies, as they may struggle to balance the costs against the potential benefits. However, it is also essential to consider that implementing technology offers vast opportunities for faster growth and more efficient use of the potential.

- ***Data Input Accuracy:*** The following problem currently encountered in logistics, including the supply chain, is that although Blockchain correctly guarantees that data cannot be changed, it cannot verify the accuracy of the entered data. This is considered both the "advantage" and the "disadvantage" of Blockchain technology. On the one hand, immutability makes the technology more secure. Still, on the other hand, if inaccurate information is entered, it will also remain unchanged, since both the errors (or false information) are entered into the system, and the real data is permanently stored in the blockchain. The former, of course, undermines trust and causes operational problems. Here, both collecting precise information and selecting the appropriate specialists are very important.
- ***Regulatory and Legal Uncertainty:*** Another problem is that blockchain's decentralized and international nature clashes with existing legal and regulatory frameworks. In many countries, the rules for its application in logistics are still unclear, so companies are hesitant to use this technology, as it can lead to problems with the legal framework. This is worrying, because one of the meanings of blockchain is that it is a connecting link between the whole world, regardless of location, and this is precisely where its uniqueness lies. Many countries (De Filippi & Wright, 2018) have already begun to develop laws that will give blockchain technology a legal basis, which will not pass by logistics. The increasing demand for blockchain seriously incentivizes governments to consider its legalization.
- ***Resistance to Change:*** Due to a lack of trust, fear of failure, or reluctance to change long-established behavior, stakeholders in traditional logistics systems may be reluctant to adopt blockchain technology. This is certainly not limited to blockchain technology or the logistics sector alone, as resistance to change and preference for traditional methods create significant cultural barriers to digitization in general, especially among the older workforce, which negatively affects the integration of digital tools into SME workflows (OECD, 2024). Along with all this, of course, the role of competent leadership and human resource management institutions is growing, in terms of improving work styles and encouraging change.

With all this, we should not forget that blockchain technology is developing rapidly, and these problems are only temporary. According to (Petersen, et al., 2018, p. 263) there is a "striking gap between the huge expectations on short-term disruptive change and ready-to-use solutions on the market". In the long term, they will find solutions very quickly. They will adapt to the global order (Marengo & Pagano, 2023), because this technology has attracted a lot of attention worldwide in recent years as an innovative and revolutionary technology of the 21st century.

3. History And Application of Smart Contracts In Logistics

3.1. The Evolution of Contracts to Smart Contracts

Contracts have been signed since time immemorial between merchants, landowners, and kings, as evidenced by the excavations of Sumer, Phoenicia, Babylon, and other ancient sites. The very essence of the contract is the formulation of agreements on any problem. Modern technologies brought forth the idea of a digital contract.

3.1.1. History of smart contract

As referred to by various scholars (Hayes, Lacovou, Benbasat, Dexter), (De Filippi & Wright, 2018) digital contracts began in June 1948, when the Soviet Union blocked the road and rail access to West Berlin. The United States and its allies responded by launching the Berlin Airlift, sending more than 2 million tons of food and other supplies to the isolated (blockaded) city. To track and organize the continuous and daily large shipments to West Berlin, U.S. Army Master Sergeant Edward Gilbert developed a “manifest system that could be transmitted by telex, radio, teletype, or telephone”.

The invention later found its way into the private sector. Gilbert, then working for DuPont, created the Electronic Data Interchange (EDI) system in 1965, developing a standard set of electronic messages to send information about the cargo location between DuPont and one of its carriers, Chemical Lehman Tank Lines. Gilbert's invention allowed DuPont to send transoceanic shipping manifests via telex messages, which were converted to paper tape and entered into the company's computers.

The expansion of EDI systems outside DuPont in the decades after Guilbert's innovation led to a trend of digitizing paper agreements and verified orders. EDI systems are widely used today, especially in complex supply chain management. The shipping, food, grocery, and automotive industries commonly rely on EDI systems to manage ongoing business relationships by exchanging electronic purchase orders, invoices, shipping bills of lading, inventory data, and various confirmations, eliminating paper documents and reducing labor and transaction costs.

EDI systems, however, have certain limitations because these electronic contracts replicate existing agreements in digital form but do not significantly change the process by which parties enter into and fulfill their commercial obligations.

Later, considering the existing gaps, in 1994, Nick Szabo first used the concept and term "Smart Contract". Another article (Szabo, Smart contracts: Building blocks for digital free markets, 1996) explored the possible applications of Smart Contracts and formulated their essence more concisely. By 1997, several algorithms and protocols suitable for the basic implementation of the idea had been developed. At that time, it was still just an idea, and the technology to implement it was created much later than this innovative idea.

Szabo states in his paper that the general goals of developing smart contracts are:

- to satisfy the basic contractual conditions (such as confidentiality, payment terms, and even the application of the contract itself),
- to reduce both intentional and accidental exceptions,
- to minimize the need for intermediaries to ensure trustworthiness.

As Szabo notes, an essential issue with smart contracts that has been largely ignored is the transfer of transaction semantics to the parties involved.

As a simple example, he presents that there is no indication anywhere whether a POC terminal placed in a store collects the customer's purchase history, and even the seller does not know how many thousands of people's data they unknowingly help collect each day (Szabo, Smart contracts, 1994, p. 1).

Since its inception, smart contracts have had many definitions. There is no universally agreed-upon definition for it. For example, when Szabo (1994, p.1) first described it, he defined smart contract as: *"a computerized transaction protocol that executes the terms of a contract*". Later, a joint article by Bodó et al., (2018, p. 6) several scholars described it as: *"pieces of code that generate transactions if the conditions encoded in them are met"*. Meanwhile, Mik (2019, p. 1) described it as *"technologies that facilitate the generation and transfer of blockchain-based crypto-assets".*

The lack of a clear definition, on the one hand, makes the scope of the topic more fluid, while on the other hand, it creates an opportunity for more comprehensive and multifaceted approaches.

The practical implementation of Nick Szabo's concept became possible in 2008 with the advent of blockchain technology, which provided contracts with complete autonomy and made it possible to abandon the third-party administrator, who served as a controller and arbitrator. Smart Contracts became widespread with the advent of Ethereum.

An Ethereum "account" contains four fields (Buterin, 2014):

● The nonce, a counter that is used to ensure that each transaction can only be made once

● The account's current ether balance

● The account's contract code, if present

● The account's storage (empty by default)

Ethereum has two types of accounts: externally owned accounts controlled by private keys and contract accounts controlled by their contract code (Buterin, 2014, p.13). This last type of account is what we commonly call Smart Contracts.

As already mentioned, a Smart Contract is a transaction that is launched and executed by a script, that is, a program, the object of which can be, for example, a simple cryptocurrency exchange or a more complex set of instructions for the execution of which the Smart Contract is used.

3.2. The Blockchain and Smart Contract

The two of the most favorite uses of Blockchain technology are "Cryptocurrencies" and "Smart Contracts". As noted by Geiregat (2018, p.1), "the former is a specific subtype of the latter", because Smart contracts are cryptographic "boxes" that store value and are only opened when X conditions are met (Buterin, 2014, p. 13). As mentioned in the previous chapter, Smart Contracts are based on Ethereum. Smart Contracts appeared later than a number of cryptocurrencies, and of course they brought certain innovations in addition to those that already existed before, for example, has the same mining process as Bitcoin, but Ethereum developed its own Proof of Work (PoW) consensus system called Ethash and a new tree architecture called Patricia Tree. The Ethereum consensus is based on the Ethash algorithm, also known as the Dagger Hashimoto algorithm (Frikha, et al., 2021). In contrast to Bitcoin blocks, which only retain transaction information, Ethereum blocks store transaction details and the most recent state of each contract and user account. Smart Contracts have much greater capabilities than Bitcoin, because they include additional features such as value-awareness, Turing-completeness, blockchain-awareness, and state (Buterin, 2014, p. 13).

Ethereum aims to combine and improve the ideas of altcoins, scripting, and on-chain meta-protocols. It is designed to allow developers to build applications that run on any consensus while providing scalability, a complete feature set, standardization, ease of development, etc.

Smart Contracts have undergone significant development since their inception. From the very beginning, their purpose was to enable the validation, security, and execution of agreements or transactions between parties in a decentralized network. Today, they are already one of the most powerful tools in developing blockchain technology. They are already widely used in many areas worldwide (Crosby et al., 2016), such as governance, crowdfunding, autonomous banking, auctions and property rights, smart homes, agriculture, logistics, and many other areas, the diversity of which makes it impractical to list them all.

3.2.1. The Ethereum Virtual Machine (EVM)

The code mentioned above, which is used to write a Smart Contract, is executed by the Ethereum Virtual Machine, or EVM.

What is it?

The Ethereum Virtual Machine is *the heart of Ethereum*, where all Smart Contracts are executed, and allows developers to create decentralized applications (dApps). It is a critical component of Ethereum's infrastructure, enabling code to perform precisely as intended. The Ethereum Virtual Machine is not physical but a virtual one that runs on thousands of computers, or nodes, that participate in the Ethereum network. This distribution of the Ethereum Virtual Machine ensures the security and reliability of the Ethereum network (Coinbase, URL). The Ethereum Virtual Machine is Turing-complete. The Ethereum Virtual Machine code can encode any possible calculation, including infinite loops (Buterin, 2014, p. 28). After this, Wood (2025, p. 14) writes that "it is a quasi-Turing complete machine; the quasi qualification comes from the fact that the computation is intrinsically bounded through a parameter, gas, which limits the total amount of computation done.”

Ethereum Virtual Machine has three main types of storage (Buterin, 2014, p. 17). It is a virtual machine that operates based on a structure known as a stack. It works on a last-in-first-out (LIFO) structure (32-byte values can be pushed and popped), where the most recently added element is the first to be accessed. Another storage type is memory, which is an infinitely expandable byte array, but it is a temporary memory. The final type is storage, a long-term memory that is not deleted after the transaction. The main difference between these types is that the first two reset after the computation ends, but the storage saves information for the long term.

As we already said, the Ethereum architecture differs from that of Bitcoin. When we were told that Ethereum contained a copy of both the transaction list and the most recent state, at first glance, this seemed very expensive because, in this case, you need to copy the previous code every time. However, Ethereum employs a different structure known as the "Patricia Tree" to manage this efficiently.

To avoid network abuse problems, a certain amount of money, called "gas" (Wood, 2025), must be paid for each transaction. The transaction is considered invalid if the account balance cannot cover the "intermediary fee".

Smart Contracts have been developed in specific programming languages as well. Gavin Wood, a British software engineer, created the Solidity programming language in 2014 (EliteBrains, URL). It was later completed by Ethereum's Solidity team, led by Christian Reitwiesner, along with Alex Beregszaszy, Liana Husikian, and Yoichi Hira.

All these innovations also give a sense of the significance of the toolkit concerning the investments made and still being made in its creation by its makers and believers in the concept. This new method offers managers a wide range of options when choosing a future working model or adjusting the one they currently have. Therefore, it is necessary to analyze the world practice available regarding the gaps and advantages of management models and their improvement.

3.3. The Use of Smart Contracts Worldwide

The global smart contracts market was valued at USD 2.14 billion in 2024. The market is projected to be worth USD 2.69 billion in 2025 and reach USD 12.07 billion by 2032, exhibiting a CAGR of 23.9% during the forecast period. (Fortune Business Insights, 2025)

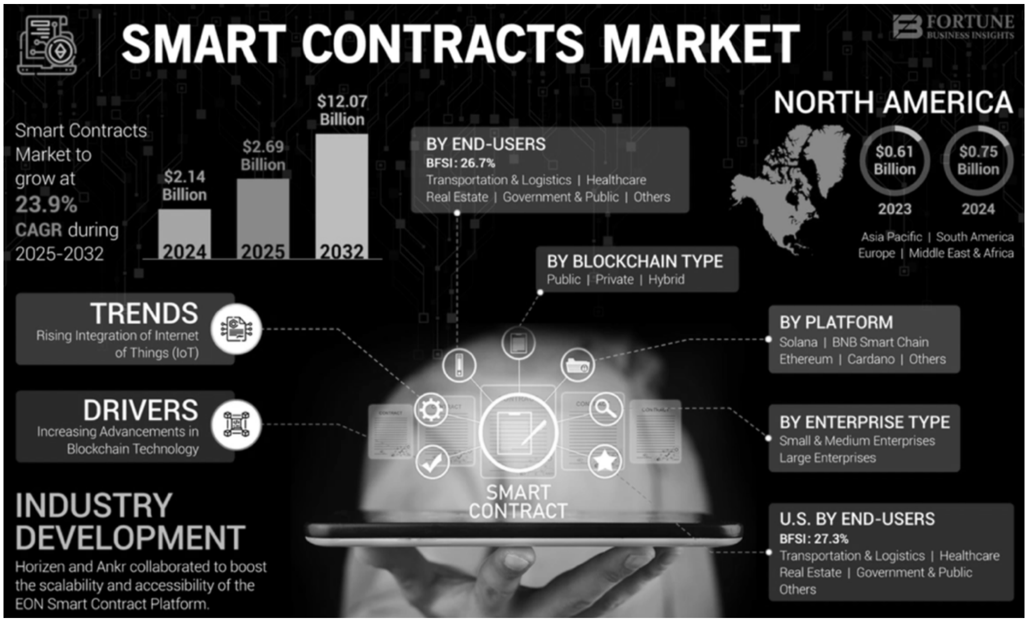

Figure 6. Smart Contracts Market Trends

Source: Fortune Business Insights, 2025

This rapid growth trend highlights the toolkit's flexibility and potential to transform traditional business processes. However, implementing smart contracts raises important questions, especially now, in the 21st century, where all technologies are rapidly evolving: Are they a necessity, an opportunity, or a challenge for modern businesses? Of course, it can often lead to concerns about whether introducing this or that technology is precisely what the company needs at that moment.

This question is especially relevant due to several circumstances; for example, new changes require financial investments, for the assessment of which not all companies have the appropriate specialists (this mainly applies to small and medium-sized companies, as well as to post-Soviet countries that have taken the path of European integration, where the negative traditions of state totalitarian management have not yet been completely overcome). Another circumstance is that technological changes are mainly stressful for employees, especially now, in a rapidly changing world, when people do not have time to develop their knowledge in line with the pace of technological development.

The proposed reformatting work also involves a certain amount of time and finances; moreover, deep down lies the personal psychological layer of a person and the fear of not being able to adapt and being unemployed, which are also a significant obstacle to making changes since a company is essentially nothing without its core team - people who share the ideas of development. However, dynamic developments require movement. The main challenge for top management in any company is not to be left out of the market because Smart Contracts are now widely used worldwide, especially in developed countries. One of the most significant problems with a traditional contract is the need for trusted individuals to follow through with the contract's outcomes. In economic terms, smart contracts' goals include reducing arbitration and enforcement costs, preventing fraud, and reducing other transaction costs.

To overcome the mentioned obstacles, it is necessary to study the tools already used in different fields worldwide, assess their appropriateness, and adapt them to the company's needs.

Despite all the challenges, smart contracts are already becoming integral to various sectors, from finance and logistics to education and art, as evidenced by the available toolkits and their widespread use. Below, I will explore practical applications of smart contracts in various sectors to show how they transform business models and drive innovation in a digital-first economy.

Music Industry: It is an undeniable fact that Smart Contracts are revolutionizing the music industry by ensuring transparency and fairness. Emerging artists depend on streaming income, especially when they are just starting out. Using Smart Contracts, artists can immediately receive royalties from streaming platforms without intermediaries. In addition, copyright management becomes automatic, reducing the likelihood of disputes and legal battles. A relevant example is Tune.fm (Tune.fm, URL), an innovative tool for music through which artists are instantly paid for every second of a song using JAM tokens. As they (Tune.FM, 2023) themselves noted back in 2023, through this tool, artists receive 10 times more money than, for example, they would receive through Spotify under the same conditions. Another example of this is *Audius,* which again is a digital streaming platform.

Art and digital assets (NFT): It is often said that the art sector receives little attention, especially among young people, but what will happen if art is digitized, which is becoming widespread today? Justin Kuepper (2023), an employee of ZenLedger, has documented, for example, using smart contracts, artists can issue a digital certificate for each of their original or printed works, which will be linked to a smart contract. This will automatically record the history of ownership of the work, and the process will be repeated with each subsequent sale. A similar platform is OpenSea, whose operations are carried out using Smart Contracts. Here, users can buy, sell and exchange NFTs, and the platform also allows you to track where the work comes from, even before it reaches the actual author, which is similiar to the process of controlling the movement of goods in supply chains. There are also other similar platforms on the market, , such as Rarible, which is considered OpenSea's main competitor.

Finance: When discussing the combination of Blockchain and Finance, it is necessary to use the expression Decentralized Finance (DeFi). The possibilities of Smart Contracts in finance are multifaceted; they can be used both to automate traditional financial functions and to perform the function itself, such as lending, borrowing, or depositing. Smart Contracts perfectly manage all the prerequisites for fraud-free transactions. A multi-layered financial network is one of the most crucial logistics components because it is precisely thanks to the flexibility that the world has become more accessible today. Here, through this financial set of tools, both commissions and service costs are reduced.

Most importantly, it saves human capital - the time, which was previously spent on queues and document circulation. There is no longer a need to visit traditional banks or financial institutions to make a transaction. As (Muayad & Abumandil, 2022 , p. 9) described transfers: “Compared to other contracts that are currently available, a smart contract is the most cost-effective option.”

One example of using smart contracts in the financial sector is Uniswap, one of the leaders in the cryptocurrency exchange market. It operates through an automated market maker (AMM) model and allows users to manage and trade their finances without the intervention of a third party. This tool is similar to Balancer, SushiSwap, PancakeSwap, 1inch, etc. Another example is Aave, a DeFi platform where you can get loans. It has a unique risk management mechanism, which makes it impossible, for example, to close loans with insufficient funds. The mechanism protects against fraud.

Education: Education is one of the most important guarantees of human development. Just as in the supply chain, where production connects to an endless number of consumers, human development - from kindergarten to infinity - is deeply tied to learning. The application of smart contracts in this area is also multifaceted; for example, diplomas are stored on the blockchain, preventing forgery and providing quick verification of authenticity. Or learncoin can be used as a currency for smart contracts created for educational purposes (Kalinkara, 2021). Blockcerts is an open platform for creating, issuing, viewing and verifying blockchain-based certificates. Another example is ODEM, an open platform that helps students understand what employers want, providing direct communication with educators, and supports students in improving their skills.

Logistics: The logistics sector is one of the key pillars of the modern economy, ensuring the efficient management of the flow of goods, services, and information from producer to consumer. In recent years, the sector has been transformed by technological innovations, making processes faster, more transparent, and safer. The development of the industry and cost reduction also open up great opportunities for other sectors because all businesses with communication channels are somehow connected to logistics, particularly the supply chain, like interconnected vessels. In general, logistics is everywhere around us, and by coordinating contractual terms and necessary parameters in this multi-layer self-activating digital code, smart contracts enable trusted transactions with visibility across the entire logistics ecosystem. Process change towards automation and digitization has enormous potential to drive efficiency gains, reduce contact costs, increase logistics process transparency, and reduce the human error probability index. Of course, there are many applications of Smart Contacts in this field, and startups such as Cargoboard or dexFreight are increasing daily. For example, CargoX, VeChain, ShipChain, and many others have been around for years and continue to develop their capabilities.

A notable DHL study noted that blockchain has significant potential to improve logistics efficiency and management. It could also significantly impact trade finance and help resolve disputes in the logistics sector. Smart contracts can be enabled with the use of digitized papers and real-time shipment data that are integrated into blockchain-based systems. These contracts can automate business procedures when the predetermined terms are fulfilled (DHL & Accenture, 2018).

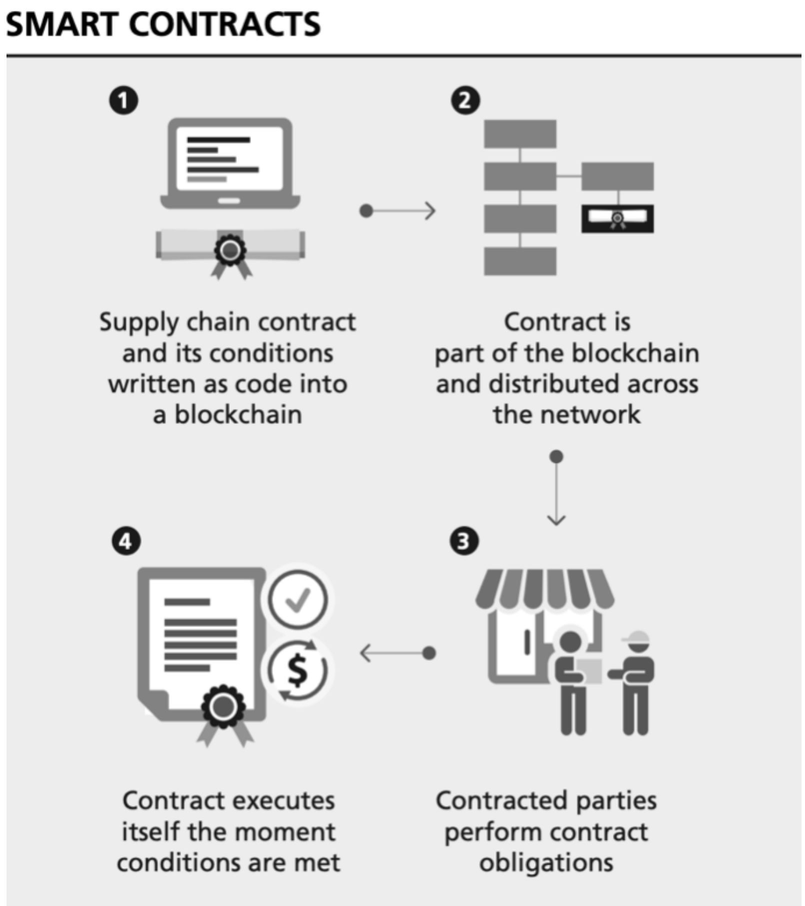

Figure 7. How smart contracts could work in the logistics industry

Source: DHL & Accenture, 2018

"Letters of credit are an important part of the trading system, but they are based on 20th century technology, not 21st. Our challenge is to take this from concept to commercial use."

That is what Vivek Ramachandran, global head of product for HSBC's trade finance business, said in 2016, when Bank of America Merrill Lynch, HSBC, and the Infocomm Development Authority of Singapore (IDA) jointly developed a prototype (FinTech Futures, 2016) for digitizing paper-based letters of credit using blockchain. This allows trade transactions to be automated through digital smart contracts. As a result, all information about the letters of credit becomes available to all parties involved in the transaction simultaneously.

The use of smart contracts in various sectors now and their potential in the future certainly highlights their ability to automate processes and increase security. It contributes to the development of industries and the scalability of sectors. However, their implementation also has challenges that can affect their effectiveness and adoption. Since logistics is the main subject of this research, it is necessary to consider how the advantages and challenges manifest themselves in logistics and supply chain, which we will discuss below.

3.3.1. Smart Contracts in Logistics: Opportunities and Challenges

In general, manufacturing and logistics have always looked for ways to improve process efficiency, reduce costs, and increase transaction transparency. Like all toolkits, Smart Contracts have advantages and challenges that drive their development.

We begin with *challenges*:

Risk of Errors in Contract Conditions (Mistake Risk): Using smart contracts in logistics and supply chains makes the risk that can occur due to incorrectly or incompletely defined prerequisites or coding issues much more pronounced. For example, suppose the prerequisite for the code to work is that the amount of freight is automatically transferred to the carrier without considering additional conditions such as product inspection or insurance coverage. In that case, payment will be made automatically, even if the goods are damaged during transit due to the carrier's fault. This can lead to financial losses and legal disputes between the involved parties.

Immutability of Smart Contracts: Immutability is a fundamental aspect of Smart Contracts, which has certain advantages that will be discussed later. For now, , let's look at the issue from a different perspective. And so this feature can become a source of significant challenges too if due to a human or technical problem, we have an incorrect information input. Changes cannot occur during the process since the information is collected and fixed. For instance, if the Smart Contract code specifies that shipment documents must be sent by email after the truck departs for the border to prepare for cargo entry, but the cargo was overlooked due to an error by the manufacturer (such as an empty box), a mistake by warehouse staff, or a technological issue (e.g., IoT sensor failure), the package of documents will still be automatically sent via email to customs when the vehicle moves, following the Smart Contract code, even if the mistake is noticed.

For example, if the previously determined route is changed due to weather conditions during delivery, additional action must be taken to notify us. It is impossible to modify a new transportation route within the existing Smart Contract, as the Smart Contract will only move to the next step if the conditions are 100% the same as in the code. Of course, there are solutions for these, but they are more expensive, such as modular coding.

Different international legal frameworks: Smart Contracts in supply chains with participants from multiple countries can face challenges due to differing legal frameworks. Determining which country's laws apply in disputes is difficult, as Smart Contracts rely on blockchain technology that excludes third-party involvement. This situation can create not only corruption risks, such as state preference in favor of the interests of a company operating in a particular country, but also significant discrepancies between different systems. Additionally, it is essential not to be excluded that the parties involved in a Smart Contract may not be limited to just two countries – there could be multiple parties from different countries worldwide. To address these issues, companies sometimes use ICC (International Chamber of Commerce) contracts or arbitration clauses to resolve disputes effectively.

In addition to the above, some blockchain platforms have attempted to mitigate this legal uncertainty void by implementing innovative hybrid solutions, where smart contract code is directly linked to traditional legal agreements, ensuring both legal and technical enforcement.

Privacy concerns: Often, logistics companies do not prefer to publicize the cost structure of their services, as such activity can lead to unwanted dumping practices to enable competitors to gain a new strategic positioning. Additionally, the complete transparency of smart contracts can sometimes be detrimental to product owners. It can expose sensitive information, such as the origins of raw materials or supply quantities delivered within a specific time interval. To solve this problem, Blockchain has the idea of encrypted users and private chains. This challenge can also be overcome in the Smart Contract code to solve these concerns in Smart Contract-based blockchain platforms by designing it with encrypted access control or permission structures, ensuring that only authorized parties can access the details of a specific contract.

Smart Contracts, in this way, not only automate transactions but also protect sensitive business information by balancing transparency with confidentiality, a very important factor in logistics and supply chain management.

However, smart contracts offer significant benefits beyond addressing these challenges, and they are already transforming and will continue to transform logistics operations in many ways. The ability of Smart Contracts to simplify, automate, and secure processes drives efficiency, reduces costs, and most importantly, increases trust among all participants in the supply chain.

This section examines the main *advantages* that Smart Contracts provide in logistics and supply chain management.

Immutability of Smart Contracts: With the continuous advancement in logistics, the risks of fraud and dealing with companies of unknown origin are also increasing. In this context, the immutability of Smart Contract code provides a reliable safeguard. Although this feature, as discussed earlier, also has its own risks, these are generally manageable. The main advantage of immutability lies in the fact that the predetermined conditions remain constant, and the program operates independently of the relationships of partners, situations, or the will and mood of any party. For instance, in logistics, if a Smart Contract stipulates that payment must be made immediately after cargo is picked up from the supplier, regardless of everything, then:

- The payment will be transferred regardless of the relationship between the supplier and the customer at that moment, whether they know each other or not,
- No party will be able to delay or avoid making a payment based solely on their own desire.

This offers significant opportunities for speed-based logistics. In the example above, payment automation accelerates the process. It reduces employee time loss, as there is no need to remember transactions, set reminders, or manually follow up. Automation monitoring requires less time if necessary. The immutability of Smart Contracts ensures that all parties are confident that there will be no deviations under normal conditions and that agreements will be implemented. As a result, the immutability of Smart Contract code ensures stability and reliability in logistics and contributes to the acceleration of logistics operations and cost reduction.

Constant Accessibility: One of the primary challenges in logistics - maintaining continuous contact with the customer - is effectively solved through Smart Contracts. Consider a scenario where there is no longer a need to call the operator or sales manager to find the exact location of your cargo; furthermore, there is an opportunity to know the approximate delivery time. This capability also provides significant benefits, particularly in the logistics sector and supply chain, because:

- Independently of language barriers, users can access real-time information at any time, even without needing to understand the other party's language, and there is no need to search for contacts to establish communication,
- The inconvenience of time zones is eliminated, since there is no need to wait for the working hours of the relevant company to receive updates,
- Customer service is automated; this helps save time and reduces disputes and the risk of human error.

Smart Contracts enable a continuously updated data stream directly from the supply chain by integrating advanced GPS and IoT systems. For example, sensors can provide information about the shipment's location and details such as its position, temperature, humidity, or other specific cargo characteristics. These parameters are recorded and monitored without human intervention.

In this case, the human resources from the call center can be redirected mainly to attract new customers or answer urgent questions. Which, of course, will contribute to both the growth of sales indicators and the professional development of specialists.

The constant availability provided through Smart Contracts ensures more efficient processes, increases the quality of customer service, and strengthens companies' market positions by providing faster, more transparent, and more flexible logistics operations.

Trust: In logistics, as in any other field, trust is essential in building business processes. However, establishing trust has become increasingly challenging in a rapidly changing world. The global order is in flux, causing certain matters to become uncertain. Long-standing alliances are now unstable, further complicating trust between business entities or individuals from different cultures.

One effective solution to this global issue is the implementation of Smart Contracts, which offer trust without requiring personal trust. It is unnecessary to trust the other party, and it is not even essential to know them before entering into a transaction. All conditions are specified in advance, and the process proceeds only when these preconditions are met. Consequently:

- Companies of varying sizes can cooperate as equals based on an "if this, then that" principle,
- Neither party can unilaterally alter the conditions or breach the agreement,
- Reputation and market position are irrelevant; the primary factor is the fulfillment of predefined conditions.

Thus, Smart Contracts in logistics provide not only transparency, accessibility, and trust among participants but also transform the culture of building partner relationships within the industry.

4. Logistics And Modern Technologies

4.1. Logistics history

Any company engaged in economic activity contains some element of logistics. Logistics is fundamental in managing the flow of goods and services; it is a multi-branch and multi-polar field. However, as a science, it was formed much later; its historical roots go back to the depths of human history. Logistical considerations play a strategic role in business.

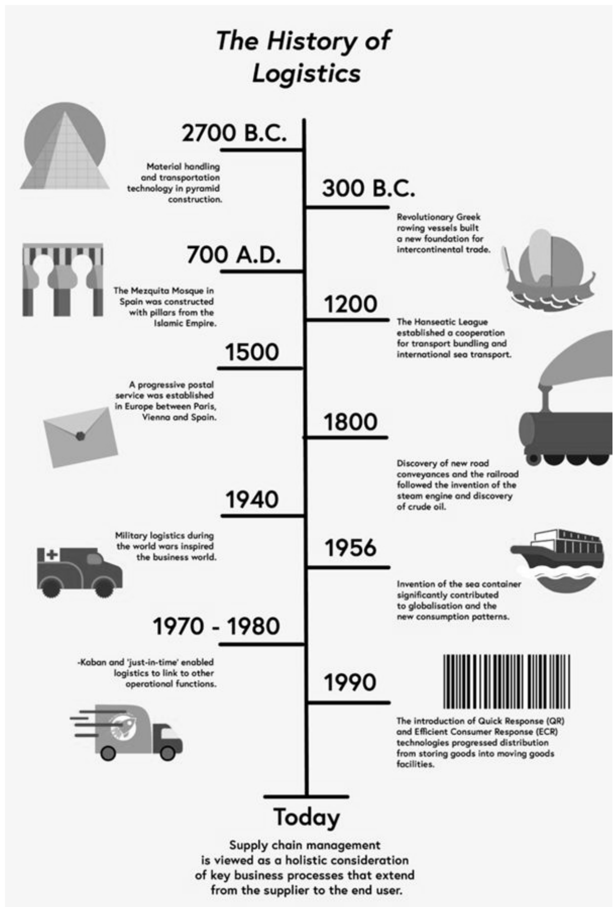

Figure 8. The History of Logistics

Source: Unknown author, widely circulated on the internet. (Howell, 2023)

Sometimes we met a theory that the ancient Egyptians probably established the first logistics department (SCM EDU, URL). Economists separate two significant areas for defining logistics in professional literature. The first is related to managing all the functions needed to get the product from the supplier to the consumer. The second direction is broader; it also includes the coordination of supply and demand, market analysis, and the coordination of the interests of industry participants (Slock & Lambert, 2005, p. 120).

However, there is still no unified definition for logistics, which is typical of all newly developing sciences. Still, since humanity has been aware of logistics for a long time, different scientists worldwide have defined it.

For example, Jenkins (2024, p-1), speaking about the strengths and weaknesses of logistics, writes; “Logistics refers to the movement of goods from Point A to Point B, which entails two functions: transportation and warehousing”.

Gadzhinski (2007, p-13-14) stated that logistics is the science of material and related information flows, and that, as a direction of economic activity, its essence is the management of material flows in the spheres of production and circulation.

As mentioned, Christopher (2016, p-2) in his book “Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders”.

SCM EDU describes logistics as "the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information".

As mentioned, Li (2014, p-1) “Logistics is the management of the flow of goods between the point of origin and the point of consumption in order to meet some requirements”.

As for us all the definitions are correct because logistics is not only about one process it included whole management from beginning to customer, and sometimes even after it. Logistic processes are not only about warehousing and transportation, but it is also about the strategical planning, and informational flow. Given its characteristics, the logistics industry must stay abreast of the business cycles of all other sectors. The main task of logistics is to identify reserves for reducing costs in storage, procurement, loading, unloading, production processes, and product transportation, and to select the optimal option in terms of logistics costs. To make the optimal choice, it is necessary to find the cheapest option and avoid unwanted risks. Since everything happens transparently, blockchain technology makes it possible to minimize trust risks.

4.2. Types of Logistics

Logistics is an integral part of modern business, and its importance continues to grow. The rapid development of technologies and globalization has led not only to the fact that logistics has become a convenient tool for cost optimization, but also, from a strategic point of view, a powerful means of increasing competitiveness.

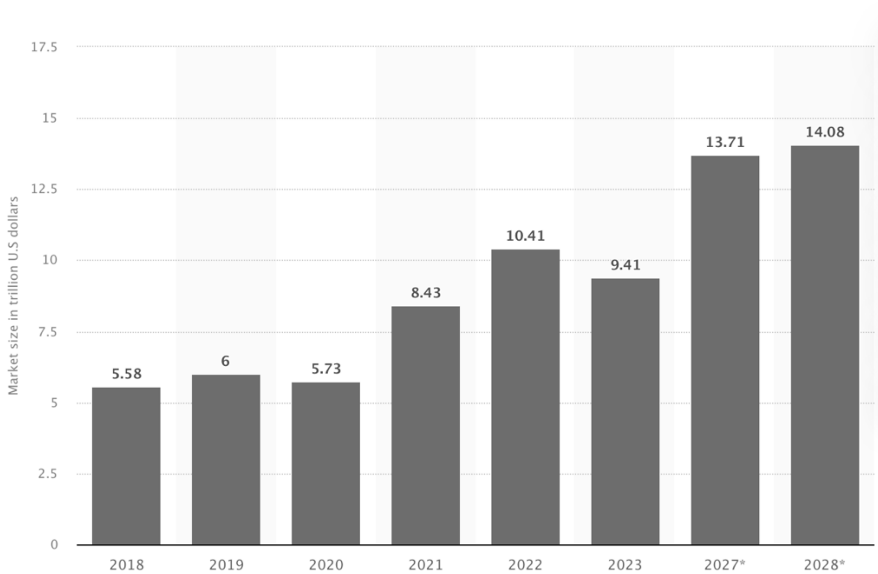

Figure 9. Size of the global logistics industry from 2018 to 2023, with forecasts until 2028 (in trillion U.S dollars)

Source: Statista, 2025

Figure 9 depicts the steady growth trajectory of the global logistics industry from 2018 to 2023, reflecting its increasing strategic importance in international trade and economic development. This growth will continue steadily, reaching approximately US$14.08 trillion by 2028. Such expansion highlights the industry's resilience and adaptability to global economic uncertainties, supply chain disruptions, and shifts in consumer demand. A variety of logistics operations and processes drive the growth of this market. Understanding each logistics type's specific roles and functions is essential to optimizing supply chain efficiency. The main types of logistics include various processes, thanks to which the supply of goods and services becomes more efficiently managed. They are:

- *Procurement Logistics:* It is considered a subarea of logistics. It describes the process from purchasing raw materials or semi-finished products to their transportation to the receiving store or production line, ensuring the continuity of production or other methods. In the logistics process, purchasing logistics is located between the supplier's outbound logistics and the manufacturer's production logistics. (Time:matters, URL)

  There are some responsibilities for them:
  - The correct quantity of products is obtained,
  - The products arrive exactly when required (just in time),
  - The products meet the expected quality standards.
- *Warehousing Logistics:* This type of logistics is responsible for storing and sorting cargo. It includes the proper storage, labeling and correct packaging of cargo. Data for the sorting and sallning of all cargoes is received from this link. Storage conditions also play a vital role here, for example, there

are special refrigerators for perishable cargoes, or medicines require other special conditions for storage. With modern technologies, in particular robots and automation systems, these processes are already available faster than human labor. For example, as noted by employees of the leading shipping line in the industry, Maersk, (Maersk, URL) the use of robots in warehouses allows for even faster loading and unloading, and ensures work on a 24/7 system, which is especially important during periods of high demand (peak seasons). This allows you to reduce errors associated with the human factor and significantly increases the efficiency of cargo transportation processes. Automation and AI are becoming cornerstones of logistics, particularly in warehousing. AI-powered predictive analytics and collaborative robots (cobots) increase productivity and efficiency, address labor shortages and enhancing demand forecasting (Nomadic Software, 2024).

- *Distribution Logistics:* This branch manages the efficient movement of goods from warehouses to end consumers. It includes order packaging, processing, transportation and delivery optimization. Distribution logistics has become an important center, especially after the growth of e-commerce. Companies now use route optimization software (such as Descartes), AI also plays a vital role in this organism, thanks to which it is possible to increase the accuracy and efficiency of the above programs through demand forecasting tools and automated systems (Kshetri, 2018).

  Drones are also being considered to solve urban delivery challenges, which can only work for small and specific volume loads.

  Logistics operations are also significantly improving the connectivity of IoT devices and systems (Hussein & Muhudin, 2024, p. 3). Smart contracts further simplify distribution logistics by automating delivery confirmations and payment triggers, reducing administrative costs and increasing transparency (Kshetri, 2018). These innovations also support environmental goals.
- *Information Logistics:* The goal rests on accurately capturing information about the whereabouts and movement of materials, people, and equipment. Information Logistics is a multifaceted type. The efficiency of the entire flow depends on accurate information, but in addition to accuracy, it must also be at the right time and in the correct quantity. It is essential to have a precise working document flow and archive, which will allow you to return to completed transactions at any time for analysis. A logistics information system (LIS) is designed to support all logistics processes, including material flow, coordination of logistics activities, and inventory replenishment. (Lambert et al.,1998). However, as Haftor et al. (2011) reviewed in the “Review of Information Logistics Research Publications,” Information Logistics includes information and communication technologies as a key component. Modern technologies also solve many of these problems. RFID systems and the latest IoT technologies create significant opportunities for management circles to store and transmit information more easily and safely. From the dawn of history, one of the current problems in logistics has been not responding in time, which can lead to severe financial and operational losses. The use of smart contracts makes it possible not only to speed up the process

of transactions through the clear transmission of data, but also to ensure high confidence in their compliance with reality, reducing the possibility of human errors and illegal interventions.

- *Transportation Logistics:* This type refers how several forms of transportation (trucks, ships, airplanes, and trains) manage and coordinate the actual physical movement of materials and goods (Translogistics Inc., URL). The primary responsibilities of transport logistics include: Ensuring timely and cost-effective delivery of goods, choosing the most suitable type of transportation depending on the characteristics of the cargo and the wishes of the customer (FTL (Full Truck Loading), LTL (Less than truck loading), FCL (Full container loading), LCL (Less than container loading)), etc., Of course, we cannot fail to mention that this entire process must be under constant supervision and appropriate control so that responses are appropriate and timely. Companies often chooce transportation based on priorities such as time, price, quality, or simply internal concerns. To better understand the role of different means of transport in logistics, the following table summarizes their advantages, disadvantages, and typical application area.

Tabel 1. Pros, cons, and common uses of various transport methods in logistics.

Transport Mode	Advantages	Disadvantages	Application Areas
Road	- High flexibility, - Door-to-door delivery, - Fast delivery over short and medium distances	- High operational costs - Dependence on road infrastructure and weather - Traffic congestion	- Short and medium-distance transport - Light and medium-weight goods (e.g., groceries, furniture, household appliances)
Rail	- Cost-efficient for heavy and bulk goods, - Low transport costs over long distances, - High safety	- Limited flexibility (not door-to-door) -Dependence on rail infrastructure - Requires transshipment to other modes for final delivery	- Heavy and bulky cargo (e.g., coal, metals, construction materials) - Long-distance transport within or between countries
Maritime (Sea)	- Low freight rate per unit - Suitable for transporting large volumes (dry and liquid cargo) - High efficiency in international trade	- Long delivery times - Weather and seasonal dependency - Requires ports and infrastructure for storage	- International trade - Large and heavy goods (e.g., oil, coal, grain)
Air	- Fast delivery - Minimum transit time - High transport security	- Very high transport costs - Weight and volume limitations - Weather dependency	- High-value, and perishable goods - Products requiring maximum delivery speed
Pipeline	- Continuous flow and low operational costs - High level of automation and safety - Energy efficient:	- Limited to liquid and gaseous cargo - Infrastructure expansion is limited (requires pipeline construction)	- Oil, gas, chemicals, and other liquid/gas cargo
Pneumatic	- Suitable for small and light goods - High speed and low operational cost	- Limited capacity - Restricted routes	- Transporting small items and packages (e.g., in banks or postal services)

Transport logistics is one of the pillars of the global economy, ensuring the efficient flow of goods and services across borders and continents. With the acceleration of globalization and the increasing complexity of supply chains, transport logistics has evolved from a simple support function into a strategic pillar of a particular competitive advantage. Its practical application not only ensures the timely delivery of goods but also optimizes resources, reduces operating costs, responds to dynamic market demand, and helps to realize the increasingly modern concept of a waste-free world.

The transportation of goods is closely linked to the development of the global economy. Countries with well-developed transportation and logistics systems, such as Germany, the Netherlands, Singapore, China, and the United States, dominate the world's logistics networks. These countries have successfully developed infrastructure, technology, and policies to make cross-border trade more efficient and transparent.

It is worth noting that the global logistics sector is susceptible to geopolitical tensions and international crises. Recent global events, such as the blockage or disruption of major logistics arteries due to military conflicts or political instability, highlight the importance of resilient logistics strategies. For example, the closure of the Red Sea during recent conflicts significantly disrupted global maritime trade routes, underscoring the vulnerability of global supply chains and the need for alternative transportation routes and methods. The closure of the Red Sea not only caused delays as ships had to bypass the danger zone around Africa but also raised freight rates and shook the global market, as shown in Figure 10.

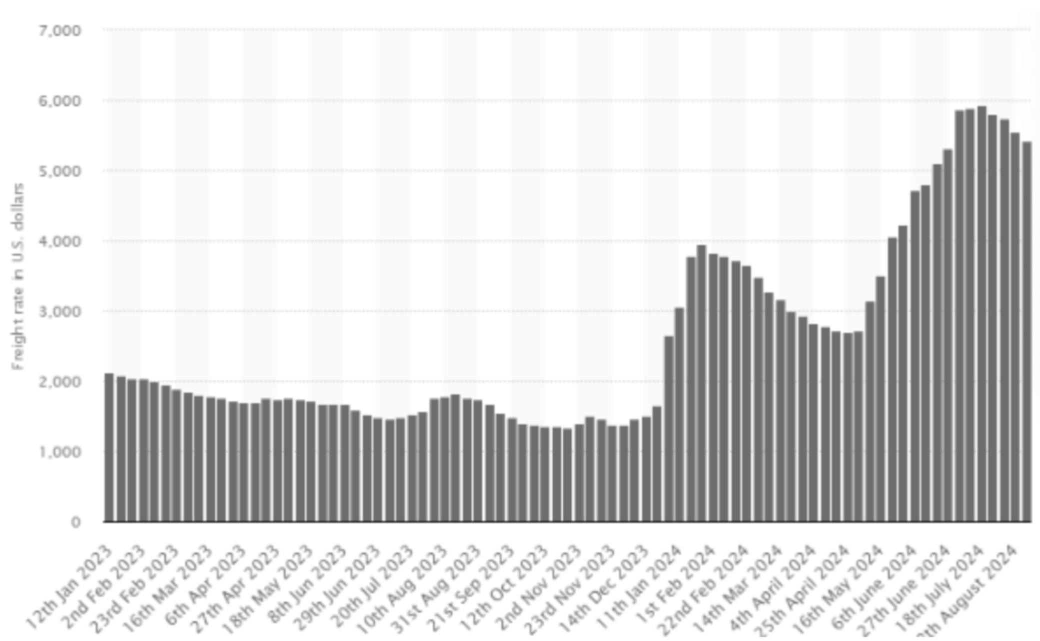

Figure 10. Global container freight rate index from the 12th January 2023 to the 15th August 2024

Source: Lövenich , 2024

Transportation corridors such as the Suez Canal, the Panama Canal, and major straits (e.g., the Strait of Hormuz and Malacca) represent essential hubs for global logistics. Any disruption in these strategic locations leads not only to immediate logistical complications but also to significant economic consequences on a worldwide scale. Such events demonstrate the need for robust risk management practices in logistics operations to mitigate potential disruptions.

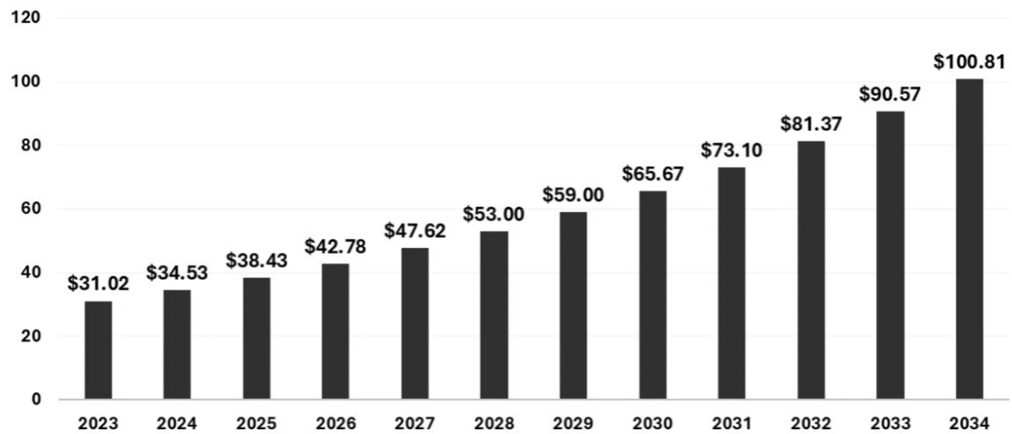

Figure 11. Freight Transport Market Size 2023 to 2034 (USD Billion)

Source: Precedence Research, 2024

As the logistics and freight markets expand (Figures 9 and 11), the need for smarter, faster, and more resilient systems becomes apparent. This is where digital innovations, particularly the Internet of Things (IoT), play a transformative role.

4.1.1.1. The Role of Internet of Things (IoT) in Transport Logistics

Unforeseen events, known as force majeure, reshape (revise) both previous solutions to problems and the market itself. For example, when the real estate market crash began in the United States in 2008, the world faced one of the biggest crises since the Great Depression. The recent coronavirus that shook the world was unpredictable; many call it a "black swan," leading to great chaos in all areas. Logistics, of course, cannot only be isolated from world events, but is also directly involved in the management systems of almost all levels. Modern tools like the Internet of Things (IoT) can reduce unpredictability. The use and integration of IoT technologies with logistics infrastructures can lessen the negative impact of such situations. For example, IoT sensors can understand the location and conditions of cargo (temperature, humidity, etc.). They can detect and respond to emergencies, detect hazards and prevent crimes in real time, detect damage to infrastructure such as roads or bridges, and inform the relevant authorities. For example, seismic sensors perform an early warning function for earthquakes, which makes it possible to choose the optimal route for cargo transportation in advance and avoid damage to cargo or, more importantly, loss of human life. All this improves the efficiency of logistics services and ensures compliance with the primary goal of logistics - the rule of the 7Rs. (Getting the Right product, in the Right quantity, in the Right condition, at the Right place, at the Right time, to the Right customer, at the Right price. (FutureLearn, URL))

IoT integration in transport logistics has already proven its value through practical applications. In partnership with IBM on the TradeLens project (Jensen et al., 2019), companies like Maersk have used the Internet of Things for real-time tracking, including data such as container numbers, temperature readings, and electronic seals. This system created a role-based, permissioned data sharing model, where each stakeholder, from the port terminal to the land carrier, could access only the data they were authorized to see, which improved transparency and data security. This platform was closed in 2022, as the companies announced (Maersk, 2022), but it serves as a basis for more efficient and non-monopoly models.

Moreover, IoT is being used in freight security through integrated systems that follow the "Deter – Detect – Delay – Respond" model. For example, suppose an unexpected weight change is detected or a seal is broken. In that case, the system can alert relevant parties immediately (Bauk, Blockchain conceptual framework in shipping and port management, 2022). Such integrations are essential not only for efficiency but also for reducing risk and supporting insurance verification. For example, Pal and Yasar's (2020) recent study suggested implementing a blockchain-based ledger as a conceptual framework for enterprise information systems specifically designed for IoT applications. However, stakeholders in the process may have their databases, which can naturally hinder data exchange between all stakeholders. Data or information updates may also be delayed because data and information are collected and transmitted manually. Due to the lack of real-time data and information, logistics resources may be used inefficiently, leading to energy waste and the inability to make dynamic decisions, which can result in unmet requirements (Tan et al., 2020). Therefore, logistics today has this challenge, as creating strong connections between stakeholders is necessary. Proper distribution of data and information in real time is crucial.

To address these issues, IoT needs to be seen as part of a broader systemic transformation. Experts recommend that businesses fully understand the root cause of their logistics challenges before implementing any technology. Systems thinking and a holistic approach are key. IoT implementation is not just about innovation but solving existing pain points without creating new ones.

In terms of infrastructure, IoT devices require robust connectivity, real-time processing capabilities, and robust security systems. For example, temperature monitoring devices must withstand harsh conditions, provide instant feedback, and ensure data integrity during transmission. The choice between Wi-Fi, Bluetooth, or cellular networks depends on the use case, power constraints, and environment.

In summary, the world's pace of change is driving the logistics industry towards more integrated, automated, and intelligence-driven systems. With the emergence of fourth-, fifth-, and now even sixth-party logistics (4PL–6PL) models, businesses are embracing platforms combining physical and digital logistics. In particular, 6PL logistics represents a leap towards smart logistics, powered by artificial intelligence, the Internet of Things, blockchain, and automation. These innovations enable real-time tracking, predictive analytics, and automated warehouses and vehicles, but also bring challenges such as high technology dependency. As the logistics industry evolves, traditional freight forwarders must reassess their position in the value chain. Those that embrace digital transformation and proactively adopt advanced logistics models will be best positioned to compete in the global marketplace.

Although blockchain, the Internet of Things, and artificial intelligence do not have a vast life experience if we look at them from a historical perspective," the potential benefits are vast" (Idrissi et al., 2024, p. 10).

5. Armenian economy, logistics companies and blockchain-based roadmap

5.1. Armenian Economy

A reputable international report states that despite the complex challenges of recent years (OECD, 2024) such as COVID-19, the Armenian-Azerbaijan war, and the unresolved issue, Armenia has demonstrated notable resilience, registering stable economic growth since 2020. Of course, this development has also been stimulated by other external circumstances, including the influx of migrants (i.e., relocated specialists), businesses, and capital caused by the Russian-Ukrainian war. As a result, Armenia positioned itself as the fastest-growing country in Eastern Europe and Central Asia in 2022, with a 12.6% (Belacin et al., 2025) GDP growth. The country's Information and Communication Technology (ICT) sector grew by 20%, accounting for 4.5% of Armenia's GDP in 2022. Armenia is indeed a mountainous country with no access to the sea to use underwater cable connections, which slows down the speed of Armenia’s Internet. In this way, it is lagging behind Eastern European countries and its neighbors, but it is trying to resolve this issue through diplomatic relations. Due to geopolitical imperatives, Armenia joined the Customs Union within the Eurasian Economic Community (EurAsEC) framework. In 2015, it signed the EAEU (Eurasian Economic Union) agreement, created under the leadership of Russia. In 2017, Armenia joined the EAEU’s digital initiatives, including adopting blockchain technologies. As a result, it participates in regional blockchain projects and carries out real-time exchange of experience. Here, it is essential to consider the opportunities and differences between the EU and the EAEU. The table below presents a percentage-based comparison between Armenia, V4, and EU countries regarding the use of technologies, segmented by company size. However, it is necessary to note that the comparison is not objectively fair, since the Visegrad countries are only former socialist countries, while. Armenia is a post-Soviet country in Russia's economic and political sphere of influence.

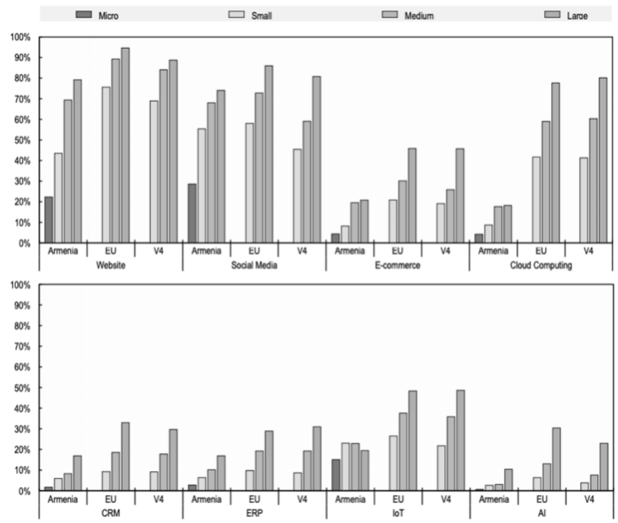

Figure 12. Percentage of enterprises using the technology

Source: ARMSTAR, 2023, Eurostat for EU and V4 countries

Despite the above-mentioned objective constraints, unlike some African and Asian countries, in Armenia a) the law (Government of the Republic of Armenia, 2004) stipulates that an electronic signature has the same legal force as a handwritten signature, b) the government has an e-government platform, e-gov. Am reflects the country's aspiration to make digital platforms a policy priority. This government platform allows, for example, the carrying out of several transactions online using an electronic signature. All of this highlights the country's orientation toward technology-driven development. The government is actively promoting the growth of the IT sector in line with the key objectives of the 2021-2025 Digitalization Strategy of Armenia (DSA). The Ministry of High Technologies of the Republic of Armenia implements government-funded programs to advance digital skills nationwide (OECD, 2024).

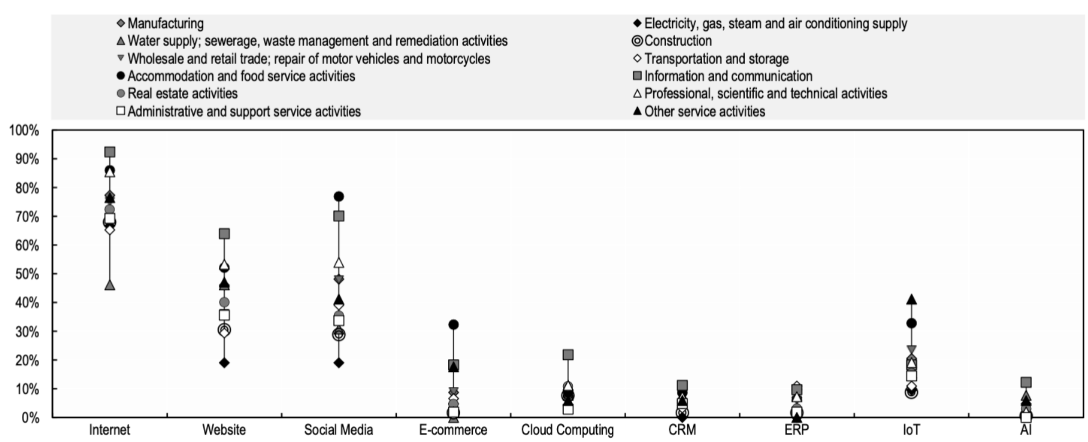

Figure 13. Percentage of enterprises using the technology in Armenia, 2023

Source: ARMSTAT, 2023

Focusing more closely on the transport logistics sector in the infographic, we can see that internet usage in this field fluctuates between 60% and 70% in the country. For websites, we have a lower percentage of 30%, for E-commerce it is nearly 10%, CRM systems range between 0% and 10%, and IOT usage falls within the 10% to 20% range. Thus, these statistics prove that the state's logistics companies are not using the potential of the latest technologies, which is also evidenced by the responses, ignorance and constraint of the companies that contacted us.

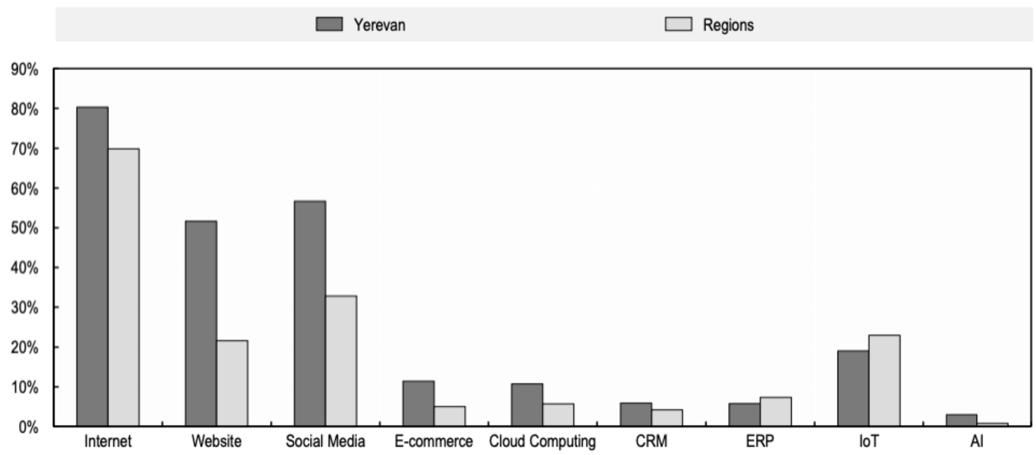

Figure 14. Percentage of using the technology, 2023

Source: ARMSTAT, 2023

According to (ARMSTAT, 2023) statistics, E-commerce, Cloud Computing, and CRM programs in the capital Yerevan differ significantly from the use in the regions, which is again logical, considering the specific development patterns shaped by the Soviet past. Interestingly, Internet of Things (IoT) technology is more widespread in the regions than among businesses operating in the capital.

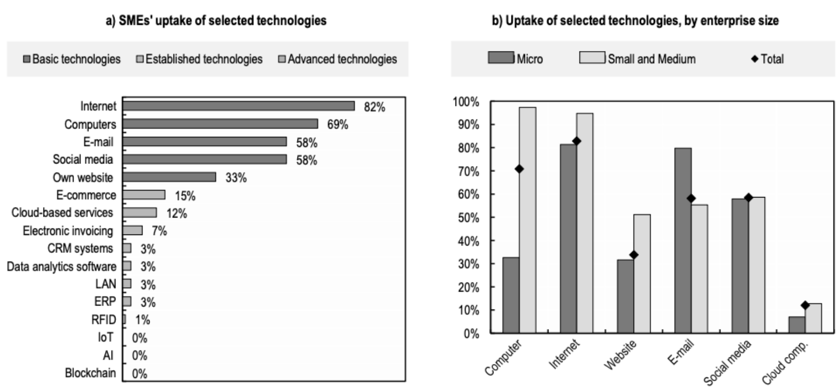

Figure 15. SME's adoption of selected technologies

Source: OECD calculations based on World Bank (2020)

According to statistics, 82% of all SMEs in Armenia that employ two or more people have access to the internet, mainly through a fixed broadband connection. To some extent, the differences are related to the size of the enterprise: 81% of micro-enterprises have internet access, while 95% of small and medium-sized businesses do (ARMSTAT, 2023). Notably, in terms of internet speed, 31% of companies in Armenia operate with bandwidths between 30 Mbps and 100 Mbps (OECD, 2024). In addition, medium and large companies are more likely to use higher-speed connections, between 500 Mbps and 1 Gbps.

The picture is different in the case of the use of e-mail addresses. Of course, it should be noted that it is more common for business purposes among SMEs operating in the service sector, such as logistics, information technology, real estate, etc. However, the difference in e-mail usage between micro, small, and medium-sized enterprises is 25 percent, with micro enterprises showing a 55% level of adoption compared to 80% for small and medium-sized enterprises. This once again indicates that paper-based processes still dominate in micro enterprises. In contrast, small and medium-sized enterprises do show an inclination toward integrating new technologies, though they still rely on time-consuming tools.

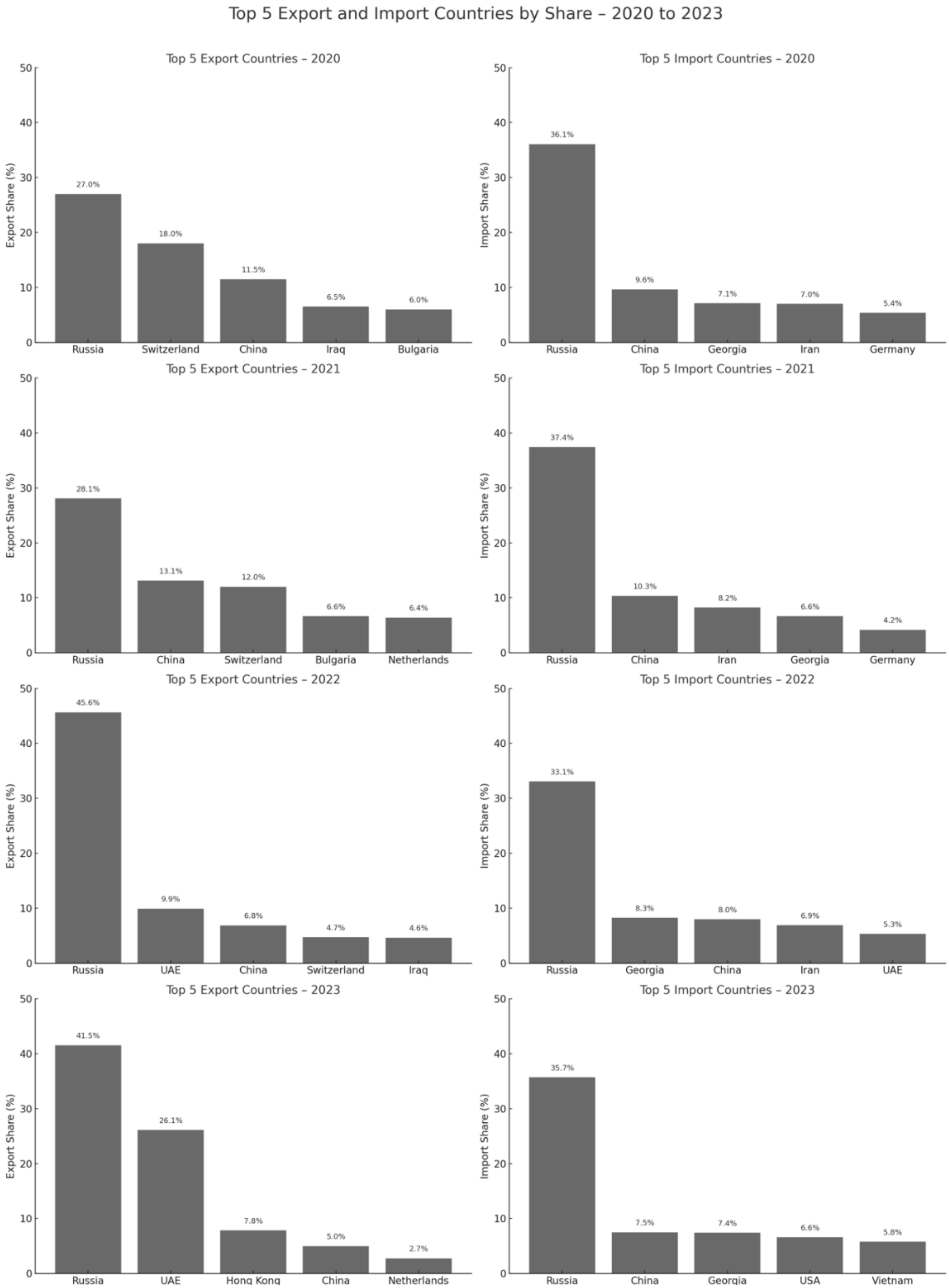

Figure 16. Top 5 Export and Import Countries 2020-2023

Source: ARMSTAT, 2023

These infographics present the structure of Armenia's exports and imports by major trading partners from 2020 to 2023. Data for all years show that the Russian Federation dominates Armenia's foreign trade system - economically, logistically, and strategically. After the 2020 war, this dependence has been maintained and increased in both volume and structural density.

Even though a reputable international report (OECD, 2024) states that Armenia has significant potential to be considered a technologically advanced country, because there are both qualified professionals (this is evidenced by the high demand for Armenian IT specialists in the global labor market and their continuous flow to the technological and information structures of various countries and prominent international organizations) and several political limitations nevertheless constrain an appropriate environment, Armenia. Along with these is its membership in the CIS, CSTO, and especially the EAEU, which continues to keep Armenia within the Russian post-Soviet orbit. Despite its potential and drive, Armenia is forced to go through various synchronizations due to its membership in the EAEU. This is mainly because companies continue to keep much of their internal working methods secret, avoiding innovative technologies (it should be noted that during the interviews it became clear that there are logistics companies that still use the Skype (Microsoft, 2024) application, noting that the link to Skype is available in the data about freight forwarders on the Russian ati.su website. However, since May 2025, the program has not officially been operational. As a result, many data and partners are impossible to find), identifying them as a possible danger of becoming dependent on another party again. One of the freight forwarding companies in the Armenian market tried to create a platform, but it is centralized and owned solely by the company itself. It is still operational today, but the activity on the platform is minimal, even in the case of marketing campaigns. And the primary reason for this passivity is not the wrong choice of target audience, but because there is an imperative to work with a synchronous culture in the EAEU rules. Each Armenian company, in one way or another, works with an EAEU entity, which in turn operates under a traditionalized culture, where key components include secrecy, mutual distrust, and hypothetical corruption risks. This atmosphere of heightened caution is also projected into intra-Armenian relations, and preference is given to working with familiar contacts, even at the cost of qualitative concessions.

Meanwhile, blockchain integration aims to solve the problem of trust, the gradual implementation of which requires a patient approach. This trauma was also expressed during our work by encountering maximally closed information, evasive answers, and blurred answers due to suspicion. Nevertheless, we collected data from several companies, some of which agreed to participate only under the promise of anonymity. Of course, we are deeply grateful to all those organizations that found the courage to respond to our questions. With all this, taking into account the above circumstances, we cannot place 100% confidence in this information. The misfortune of this approximation is specific not only to the economies of Armenia, but also to all post-Soviet countries that still revolve in the orbit of the Russian metropolis, the successor to the Soviet one, and therefore mainly work according to its principles, imperatives, methodology, work culture, and organizational psychology.

5.2. Blockchain-Integrated Logistics Process Model

In the Armenian reality, information about requests often has to be entered and re-entered in multiple systems or communicated informally through personal contacts. This not only leads to delays and errors, but also fosters operational dependence on individual employees. This approach is still prevalent in Armenia's logistics sector, as the constraints of being a member of the EAEU limit institutional transparency and hinder scalability, making the entire process vulnerable to human error. Emerging technologies such as blockchain and smart contracts provide a locally relevant and impactful solution to modernize and streamline logistics operations in Armenia.

Blockchain provides a shared, tamper-resistant ledger that increases transparency and traceability while reducing administrative burden. Armenian companies addressed issues we concluded during our research.

Smart contracts (self-executing programs on the blockchain) can automate workflows by executing tasks (such as initiating a payment or updating the status of a shipment) when predefined conditions are met.

Integrating these technologies, both global best practices and localized observations, can certainly transform the logistics environment in Armenia, improving trust, security, and coordination between stakeholders. On the other hand, integration depends not only on the qualities of companies or the level of human development, but also on the geopolitical agenda. Because of the latter, developments are delayed in such a sensitive sector as logistics. This section reviews each stage of the traditional freight logistics workflow, based on objectively observed operational gaps in Armenian companies, and demonstrates how blockchain-based tools can address these specific inefficiencies, highlighting the improvements at each stage. Based on the results of our interviews with Armenian logistics companies (the companies mostly wished to remain anonymous), as well as on data collected from my own academic and practical work experience over the years, the following presents traditional process, according to the road steps, and our proposed model, along with its corresponding steps.

Step 1: Freight Request Receipt (Blockchain-Based Initiation)

Traditional Process: The shipping process begins when the customer submits a freight request (by email, phone, or messaging) to the logistics provider's sales department. This kicks off the coordination process, the description of this process was also confirmed by several companies operating in the sector, including "Armenia Travel+M" LLC, "MiraTrans" LLC, and "Cargo" LLC, whose representatives noted that the cargo transportation process, as a rule, begins like this, which leads to the isolation of data and the need for further manual entry, and since the results of the calls are collected manually by the employee, sometimes it is necessary to repeat the request several times.

Blockchain-Integrated Model: The customer or shipper submits the freight request on a blockchain-based platform. This could be a decentralized application (DApp) where the request details are recorded as a transaction on a shared ledger. The request data (e.g. cargo type, weight, dimensions, origin, destination, etc.) is time-stamped and immutable, providing an instant single source of truth accessible to authorized participants. For example, a logistics provider can issue a "load tender" (freight request) on the blockchain; all carriers in the network can immediately view it, ensuring no time is lost in communication. Unlike emails that might be overlooked or edited, a blockchain entry is tamper-evident and verifiable by all. This transparency builds trust that the request was logged correctly and notifies all relevant parties simultaneously. Overall, Step 1 shifts from a manual, one-to-one message to an automated broadcast of the freight request via a shared ledger, reducing delays and preventing any initial data from being lost or altered.

Step 2: Data Integrity and Validation

Traditional Process: Once the request is received, the sales or operations team checks that all necessary data is provided. Key details such as cargo specifications, shipment type (FTL/LTL, FCL/LCL), transport mode, hazardous material info, temperature control needs, packaging, and delivery terms must be present. If any information is missing or inconsistent, the logistics provider must follow up with the customer to collect the missing details. During interviews, several companies, including Cargo Travel LLC, CargoExpress LLC, and others, confirmed that the information provided by customers about the cargo is very often incomplete or unclear, resulting in the need to contact them again for additional clarification. This back-and-forth communication can lead to delays and the risk of errors when updating records. An employee of MiraTrans LLC recalled how, once, a misunderstanding arose with a European partner due to incomplete information from a customer, and the vehicle left half-empty.

Blockchain-Integrated Model: Data integrity checks are automated via smart contract validation rules. (IBM, URL) has presented a guide to creating a smart contract that can be useful to a group of programmers when completing a technical task.)The blockchain platform can require that a freight request transaction include all mandatory fields before it is accepted into the ledger. The smart contract will reject or flag any submission that lacks necessary data (e.g., missing cargo dimensions or incorrect shipment type), prompting the requester to complete the info before the process continues. This ensures that incomplete data never propagates to carriers. Moreover, all parties can trust that the data on-chain is accurate and complete, since any attempt to input fraudulent or non-conforming data would be automatically detected and rejected by the network's consensus rules. In essence, the blockchain acts as a real-time gatekeeper for data quality. This reduces manual oversight – the sales team no longer needs to perform tedious checks, as the system enforces data integrity by design. It also provides a transparent audit trail of any modifications: if the customer updates a request, the change is recorded with a timestamp, and all participants can verify what changed and when, further improving data reliability.

Step 3: Tendering to Carriers and Logistics Partners

Traditional Process: After verifying the request details, the sales or operations team forwards the freight request to the logistics department, which sends it to its network of partner carriers or performs an internal cost calculation. As the companies surveyed noted, often this involves sending emails or calling external freight forwarders to solicit quotes. If the company has its own fleet, for example, one of the largest

Armenian logistics solution providers, "Spayka" LLC or “Apaven” LLC, that fits the request, an internal cost calculation is performed in parallel. "MiraTrans" LLC has a CRM system. Still, since each employee has their work database depending on the direction, this step can be slow, as it relies on individual communications and manual coordination.

Blockchain-Integrated Model: With blockchain, the freight request is automatically shared with all relevant carriers and partners on the permissioned network as soon as it is posted. Every authorized carrier node can see the new shipment request (or receive a notification from the smart contract) in near real-time. This eliminates the need for a coordinator to contact each carrier individually. Because all participants access the same shared ledger, they view identical information about the shipment requirements, pickup/delivery locations, timeline, etc., ensuring a common understanding. Platforms like TradeLens (a blockchain-based shipping network) demonstrated how a single distributed platform allows multiple parties – shippers, carriers, port operators, customs, etc. – to access and act on shipping data simultaneously, improving multi-party coordination (Ledger Insights, 2020). In our blockchain-integrated model, carriers can even register their ability to handle certain shipment types in advance, and a smart contract could automatically match the request to suitable carriers or broadcast only to those who meet the criteria (for example, only carriers certified for hazardous materials will see a DG (dangerous) cargo request). The transparency of the tendering process on blockchain prevents any one party from monopolizing information – all eligible carriers get the same opportunity to bid, fostering fairness and competition. Overall, Step 3 becomes a swift, automated dissemination of the freight request via the blockchain network, replacing dozens of emails or calls with a single shared view for all logistics partners.

Step 4: Carrier Bidding and Price Offers

Traditional Process: Carriers respond with their price quotes and terms for the shipment. The logistics department collects these offers (often via email attachments or phone calls), then manually compares them for price, transit time, and conditions, for example, "CargoExpress" LLC, "EcoLogistics" LLC use the Russian Bitrix24 CRM system (since there are specialists in that system on the market). However, comparing the received offers is still manual since the system is not flexible, while a monthly fee is also paid for technical support. After analyzing the price, the logistics provider compiles the best offer or a summary of options to present to the customer. This comparison process can be labor-intensive, and data from different carriers might be in various formats, requiring re-entry into spreadsheets or systems for evaluation.

Blockchain-Integrated Model: Carriers submit their price offers directly on the blockchain in response to the freight request. For instance, each carrier can fill a structured bid form recorded as a transaction linked to the original request. All bids are thus stored on the shared ledger, enabling the logistics provider (and if desired, the customer) to see them in real-time. Smart contracts can streamline this bidding process: the contract managing the tender could automatically organize the bids, filtering or ranking them based on predefined criteria (e.g., highlight the lowest cost or fastest delivery). Because all bids are logged immutably, there is a guarantee of data integrity and fairness – no bid can be secretly altered or submitted late without everyone knowing. This fosters trust that the bidding is transparent and not biased. In addition, the blockchain could support multi-round or dynamic bidding. For example, if allowed, carriers might see anonymized information that they are not the lowest bidder and choose to revise their offer, all handled by the smart contract rules. The result is a more efficient and potentially faster bidding cycle. By the end of Step 4, the blockchain platform has captured all carrier offers in one place, eliminating redundant data entry. The logistics provider can easily compare offers on a dashboard fed directly by the ledger data or even allow a smart contract to select the optimal bid if the decision criteria are straightforward. Throughout, security and auditability are enhanced – each offer is time-stamped and attributable to the carrier's digital identity, and no one can dispute what was offered or when, since it's verifiable on-chain.

Step 5: Final Offer to Customer and Acceptance

Traditional Process: The logistics provider presents the offer (selected carrier and pricing) to the sales department, which finalizes it and sends it to the customer for approval, in the way they communicate before. The customer then decides whether to accept the quote. If the customer rejects it, the process ends with polite notices to all parties that the bid was unsuccessful. If the customer accepts, the logistics provider notifies the winning carrier and sends formal rejection messages to the other bidders. As mentioned by the respondents, this stage often involves drafting emails or letters and possibly revisiting terms if the client negotiates further.

Blockchain-Integrated Model: Once the best bid is identified, the smart contract can automatically generate a formal offer to the customer on the blockchain platform. The customer receives a notification (or views the offer through a web portal linked to the blockchain) and can accept or reject it digitally. Acceptance might be as simple as the customer digitally signing the transaction with their private key, indicating agreement to the terms. This accepted offer effectively becomes a smart contract agreement between the customer, logistics provider, and carrier. If the customer declines, the blockchain record can automatically update the tender status to closed, and all carriers can be instantly notified (via on-chain event or alert) that the shipment was not awarded, saving time on manual emails. If the customer accepts, the smart contract executes the agreement workflow: it locks in the selected carrier and terms. It could even trigger an automatic thank-you message or on-chain notification to the non-winning carriers that the tender is closed. Because the contract and acceptance occur on a shared ledger, there is no ambiguity – all involved parties immediately see that the deal is confirmed, and the terms are recorded immutably. This digital contracting significantly reduces paperwork. As one industry analysis noted (S&P Global, 2022), traditional legal contracts can be expensive and slow to draw up, whereas blockchain smart contracts can increase transparency and "greatly reduce, if not eliminate, the role of intermediaries" in verifying and enforcing agreements. In this new model, the accepted freight contract exists as code and ledger entries (with all key terms) rather than a stack of papers, streamlining the transition into the execution phase.

Step 6: Documentation and Smart Contract Setup

Traditional Process: With the transportation agreement in place, documentation is prepared. Suppose the customer or carrier is new to the company. In that case, formal contracts are signed offline, as the representative of "EcoLogistics" LLC mentioned, however, for example, "MiraTrans" LLC, "CargoExpress" LLC, "AirCargo" LLC, and others noted that signing the contract is also acceptable in a scanned version, since they unfortunately do not yet have a digital signature. The logistics provider creates a freight forwarding application or order document containing all key details (dates, party information, payment terms, etc.). These are ready-made templates that all companies already have due to experience. This document serves as a reference for the shipment execution. For repeat business, a new application/order is typically created for each shipment. This involves populating templates and possibly faxing or emailing documents for signatures. Each party maintains its copy of the paperwork.

Blockchain-Integrated Model: The smart contract itself serves as the core documentation of the agreement. Upon acceptance in Step 5, a smart contract (or an entry in an existing master smart contract) now contains all the agreed terms: participants' identities, pickup and delivery details, timing, incoterms, payment schedule, etc. This digital contract is secured on the blockchain and shared among the parties, effectively replacing or complementing traditional paper contracts. Additional documents usually exchanged at this stage – such as certificates, permits, or export/import licenses – can be digitally attached to the blockchain record. Rather than emailing PDFs, the issuer of a document (for example, a customs broker providing an export clearance) can upload a hash of the document to the blockchain, proving the document's existence and integrity. All parties can then access the document through an interlinked system or IPFS (InterPlanetary File System) using that hash, confident that it hasn't been tampered with. We achieve a single, shared repository of all shipment-related documents and terms using the blockchain as the backbone for documentation. This reduces duplicate data entry and the risk of discrepancies. Every participant now refers to the same shipment record, rather than maintaining separate files that might diverge. Real-world platforms have pursued similar goals: for instance, the TradeLens shipping platform allowed stakeholders (from carriers to ports to customs) to manage and view end-to-end shipping data easily in one place (Ledger Insights, 2020). Likewise, in our model, once the smart contract is in place, all documentation is either embedded or referenced and accessible with appropriate permissions. This step significantly improves efficiency and trust, as nothing "falls through the cracks" – missing contracts or unsigned forms are a thing of the past, and every update is immediately visible to all. The immutable nature of the blockchain means these documents cannot be altered unnoticed, enhancing security. In short, the documentation phase is transformed into a digitized, collaborative workflow on the blockchain, minimizing paper and ensuring all parties are literally on the same page (or ledger).

Step 7: Payment and Settlement

Traditional Process: According to the agreed terms, as mentioned by the companies, the customer provides payment, sometimes full, sometimes a partial advance, as specified in the application or contract.

This could involve a bank transfer or credit payment, cash transactions are prohibited according to the law of the Republic of Armenia. Depending on the deal, the timing might be before shipment, on delivery, or net 30 days, etc. The survey participants note that this part is very relative, as it depends on the partner's choice, the cargo transportation type, and the customer. For example, "Cargo" LLC mainly works with 100% prepayment, since it pays for air cargo transportation in advance, the same goes for "SkyNet" LLC, but for example, "Air Cargo" LLC, which also specializes in air cargo transportation, mainly also accepts the post-payment working style depending on the order. Then, the logistics provider’s finance team confirms receipt of funds and, following a similar procedure, pays the selected carrier (either upfront, or upon completion, as per agreement). These financial transactions often happen through banking systems external to the logistics workflow, and reconciliation is needed to tie payments to the shipment in question. There can be delays if payments are late or disputes about invoices.

Blockchain-Integrated Model: Smart contracts bring powerful automation to the payment process. The freight smart contract established in Step 6 can be programmed to handle escrow and conditional payments. For example, the customer’s payment (or a token representing the payment obligation) can be held in the smart contract as soon as the agreement is confirmed. When the shipment is delivered (verified by on-chain events or IoT data, as in Step 10), the smart contract automatically releases payment to the carrier and the logistics provider (distributing funds as programmed – e.g., the carrier’s fee, the forwarder’s commission). This “if-then” logic ensures that carriers are paid promptly upon fulfilling conditions, and the customer’s funds are only transferred upon successful delivery, protecting both sides. In partial payment or milestones, the contract can release funds in stages (for instance, release 50% upon pickup and 50% upon delivery). Because the payment trigger is tied to trusted data (like a delivery confirmation on the blockchain), there is no need for manual invoicing and approval workflows – the ledger itself verifies that conditions have been met.

Additionally, using blockchain-based payment tokens or stablecoins, the transaction can be instantaneous, 24/7, rather than waiting for bank clearance. Even if traditional currency is used, the smart contract could emit a signal to bank payment systems to execute the transfer. The key improvement is removing redundant steps and delays: no more waiting for someone to manually issue or approve an invoice. There is no risk of human error in payment amounts or references because the contract knows precisely what is due. This automation reduces administrative costs and errors in financial settlement. As a safeguard, features like multi-signature wallets can be employed, where funds are in escrow and released only when both buyer and seller (or an arbiter) approve the outcome, assuring both parties. Blockchain integration turns the payment step into a fast, transparent, and rule-based process. Everyone can see on the ledger that payment has been scheduled or completed, and the immutable record prevents any party from dishonestly claiming non-payment. This dramatically increases trust in the transaction’s financial aspect, aligning with the broader goal of enhancing trust in a multi-stakeholder environment.

Step 8: Insurance and Risk Management

Traditional Process: The logistics provider typically secures cargo insurance in parallel with arranging the shipment. In Armenia, many intermediaries, for example, "CargoExpress" LLC, "MiraTrans" LLC and others, have standing partnerships with insurance firms and can get coverage at agreed rates. If the customer has a preferred insurer, that company might be engaged; otherwise, the freight forwarder arranges insurance to cover the cargo (often even doing so regardless, for their own protection). This involves sending shipment details to the insurer, obtaining a policy or certificate, and keeping that paperwork on file. The process is largely manual and separate from the core shipment workflow. Claims, if any, are handled through traditional insurance channels and can be slow.

Blockchain-Integrated Model: Blockchain and smart contracts streamline the insurance process for the shipment. First, the insurance policy and details can be recorded on the blockchain alongside other shipment documents, providing all stakeholders (shipper, forwarder, carrier, insurer) a single view of coverage in effect. More innovatively, the insurance could be provided via a smart contract (parametric insurance). For example, the insurer (or an insurtech platform) could deploy a smart contract that automatically pays out a claim if certain conditions are met. Imagine a clause: “If the temperature inside the container rises above X degrees for more than Y hours, pay the client $Z for potential spoilage.” Such logic can be encoded, and IoT sensors feeding data to the blockchain would trigger the payout if conditions occur . This automated claim settlement dramatically speeds up resolution – no need to file paperwork; the contract detects the incident and executes the compensation. A concrete example exists in the agriculture sector, where a crop insurance smart contract was programmed to pay the insured party if the temperature fell below a threshold for a specific duration (S&P Global, 2022). In cargo logistics, similar parametric policies can cover events like excessive vibration (indicating damage), route deviation, or delivery delay. Furthermore, if a shipment arrives damaged or late, the blockchain smart contract can automatically initiate an insurance claim or a refund process. This ties back to the transparency of tracking data: since all parties (including the insurer) have access to the trusted shipment logs, there is less dispute about what happened. The insurer sees the same sensor readings and status updates, which can trigger claims decisions instantly. Overall, integrating insurance on-chain means the insurance becomes an active part of the workflow rather than a separate silo. It enhances trust because the shipper knows compensation is algorithmically guaranteed if something goes wrong (no lengthy battles). The insurer benefits from real-time data to accurately price and administer policies. Additionally, the blockchain reduces fraud in insurance by providing verifiable data, for instance, preventing false claims because all evidence of the cargo’s condition and handling is recorded indelibly. By modernizing Step 8 with blockchain, the process of protecting the cargo is faster, more reliable, and tightly linked with the shipment’s lifecycle.

Step 9: Shipment Preparation and Document Verification

Traditional Process: Before the cargo is picked up, the logistics provider must ensure all shipment documents are in order, which was also testified to by FairyLand LLC, along with others. This, as they noted, includes verifying that the supplier (consignor) has provided any necessary documents (commercial invoice, packing list, certificates of origin, export licenses, etc.), and that the carrier has what it needs (bill of lading details, etc.). The logistics team contacts the supplier to obtain any missing paperwork and might coordinate with customs brokers for compliance. They also double-check that all conditions (packaging, labeling, regulatory requirements) are met before dispatch. If something is missing or incorrect, it must be resolved now to avoid problems later, and the customer is informed to pre-empt any future liability for delays. Once everything checks out, the shipment is scheduled to begin.

Blockchain-Integrated Model: Document verification is automated mainly and transparent in the blockchain-enabled workflow. All required documents for the shipment can be defined in the smart contract or associated checklist. As each document is uploaded or its hash registered on the blockchain (by the supplier, freight forwarder, or other parties), the system checks it off the list. If a document is missing by a specific time, the smart contract can send an alert to the responsible party (e.g., notify the supplier to provide the missing certificate). Since every document (or at least its digital fingerprint) is on the shared ledger, the logistics provider and carrier no longer need to chase papers through email – they can simply check the blockchain record to see what's provided. Authenticity of critical documents is assured by digital signatures and the immutable ledger: for instance, if a government agency offers an export permit, it can sign the document digitally, and anyone can verify that signature and the document hash on-chain, ensuring it hasn't been altered. This dramatically reduces the risk of fraud or error in documentation.

Furthermore, compliance checks (are all conditions met?) can be partly encoded: the smart contract might require a yes/no input or a document for "Dangerous Goods certification" if the cargo is flagged as hazardous. It will not allow the shipment status to progress until it's fulfilled. This ensures all conditions align with the agreed terms. In a blockchain logistics network, every participant (supplier, carrier, broker, customer) has appropriate access to the same documentation, which means the customs broker, for example, can pre-validate documents and the carrier can see in advance that everything is ready. If something isn't right, all stakeholders know the issue simultaneously and can collaborate to fix it on the platform, rather than a flurry of separate phone calls. By the time the truck/ship/plane is ready to depart, the blockchain has verified all prerequisites, and the smart contract can automatically authorize the shipment to begin. This step thus shifts from a manual, error-prone verification to a streamlined, collaborative validation of documents and conditions, backed by the blockchain security (where any missing or non-compliant element is immediately transparent to everyone). The result is fewer last-minute delays and a higher assurance that the shipment is fully prepared and compliant with all requirements.

Step 10: Cargo Transportation & Real-Time Tracking

Traditional Process: During transit, multiple actors (supplier, carrier, customer, brokers) need updates on the cargo's progress. As industry representatives noted, traditionally, the logistics department contact with the carrier via phone or email to get status reports. Updates are then relayed to the customer, often through the sales department, an internal CRM, or periodic calls. If the company has GPS tracking, for example, in the case of "Spayka" LLC, they might share a tracking link. However, in many instances, such real-time monitoring is not consistently available to Armenian companies. "Cargo" LLC, which deals with air cargo transportation, also noted that the flight data indicated on the waybill helps with tracking, but sometimes there is a need to call or write to get more specific or missing data. In the case of sea transportation, as representatives of "MiraTrans" LLC and "CargoExpress" LLC noted, international ship tracking programs, like Maersk or MSC truckings, are operational. Still, they also need to be checked by calls or e-mails, since the deadlines are very long (for example, a full container (FTL) from China arrives in approximately 45-55 days, excluding force majeure situations, and in the case of group containers (LTL), according to experts, this deadline can be in the range of 60-65 days. Also, as a result of the clashes in the Red Sea, the deadlines were increased by almost 2 weeks), and the programs are sometimes updated intermittently. According to respondents, land transportation is more uncertain in Armenia, as vehicles are mostly without tracking systems, and the only information is that received from the driver. The monitoring is often fragmented, with reliance on manual communication, which is time-consuming and may not catch issues promptly.

Blockchain-Integrated Model: IoT-integrated, real-time tracking on blockchain revolutionizes the main transportation phase. Instead of phone calls, IoT sensors and devices attached to the shipment (GPS trackers, temperature/humidity sensors, accelerometers, etc.) continuously record the condition and location of the cargo. These data points are fed into the blockchain (often through oracles) as transactions, providing all stakeholders with an up-to-the-minute view of the shipment's status. For example, as a truck carrying the cargo passes certain checkpoints or geofenced locations, a location update is automatically written to the ledger. All authorized participants (the shipper, forwarder, carrier, consignee, insurer, etc.) can check the blockchain dashboard and see these updates. A source describes this IoT-enabled tracking: sensors can log location, temperature, humidity in real-time to a blockchain, creating a trusted and untamperable journey record (Frazer, 2025). Moreover, carriers can be prompted (or their systems can be integrated) to submit status updates on-chain at key events (departure, arrival at port, customs clearance, etc.). In fact, one report notes that logistics providers and carriers can log shipment statuses (manual or automated) on the blockchain to facilitate real-time visibility for all participants (S&P Global, 2022). This is exactly what our new model implements. The benefits are significant: any delay or incident is immediately apparent to all parties. If a truck is stuck in traffic, everyone sees the delivery might be late without waiting for a phone call. Smart contracts can even be set to react to certain events during transit. For instance, if a delay causes a delivery deadline to be missed, the contract might automatically invoke a penalty clause (as mentioned in Step 8 or 7) or notify the customer with an apology and updated ETA.

Additionally, because the data is secure and shared, it reduces disputes: the customer trusts the location info (since it's directly from devices and validated on-chain), and the carrier can't manipulate reports to hide issues. Another improvement is data accessibility: whereas previously only the logistics coordinator might have complete insight (via calls and internal systems), now all stakeholders have permissioned access to a unified real-time tracking feed. This level of insight was unattainable with fragmented traditional systems. In summary, Step 10 becomes a proactive monitoring phase, where the blockchain serves as a live conduit of trusted information. The need for manual status requests is eliminated, freeing staff to handle exceptions rather than routine updates. If exceptions occur, they are also captured on the ledger, enabling quicker joint response. By coupling smart contracts with IoT, the transport stage is safer (conditions are monitored continuously), more transparent, and more efficient, fulfilling the goal of real-time cargo tracking and condition monitoring.

Step 11: Delivery, Customer Update, and Final Documentation

Traditional Process: After the cargo is delivered to the destination, the logistics provider concludes the service by giving the customer all the final necessary documents. These may include the final invoice, proof of delivery, copies of the shipping documents, customs clearance papers, and any bank transfer receipts. The customer has been officially notified that the shipment has been completed. Internally, the logistics firm also notifies all involved parties (including thanking the carriers or forwarders for their cooperation). All records are then archived, often in physical or digital storage, to close out the transaction. The process officially ends here.

Blockchain-Integrated Model: In the blockchain-enhanced model, the moment the delivery is confirmed (say, the receiver signs on a blockchain-connected device or an IoT sensor registers the container being opened at the destination), a final smart contract event is triggered to mark the completion of the delivery. This immediately updates the status on the shared ledger to “Delivered” and could automatically share a delivery confirmation with the customer. . The customer has likely followed the shipment via the blockchain portal, so they know the arrival in real time. Now, instead of waiting for an email with documents, the customer can retrieve all necessary documents from the blockchain system. The smart contract might have generated the invoice automatically (if, for example, final charges depend on actual delivery time or weight, the contract could calculate any difference and publish the final invoice on-chain). All relevant documents – including those added in Step 9 and any new ones like a signed delivery order or a digital bill of lading endorsed to the consignee – are already accessible in the ledger’s document store. In other words, document transfer is largely obviated; the customer is granted permission to download or view the digital originals on the blockchain. Because these records are tamper-proof and verifiable, they serve as legally valid proof of delivery and contract fulfillment.

Additionally, any other stakeholders (banks, regulators, etc.) who need the records can be permissioned to access them as needed. (Henry et al., 2023) report envisions such a scenario: providing customers and regulators visibility into the supply chain and “irrefutable proof” that standards and obligations were met, precisely what a blockchain ledger with final documents can furnish. With delivery confirmed, the smart contract can also automatically release any remaining payments (as covered in Step 7) and finalize the transaction by, for example, logging a completion timestamp and perhaps minting a token or NFT that represents the delivery receipt for the customer.

The closure notifications can be automated as well: the blockchain can message all participating nodes that the shipment is completed. For instance, the carrier and any brokers see a completion status and could receive an auto-generated thank-you note from the system. Since the process data is all in one place, management can easily extract performance metrics (transit time, on-time delivery, etc.) from the ledger. Finally, archiving is inherently taken care of – the blockchain permanently archives the entire history of this shipment in a secure, immutable manner. This is a stark improvement over traditional archiving in local files; now the record cannot be lost or falsified, and it's readily available for future reference or audit. As (Henry et al., 2023) puts it, a blockchain-based supply chain provides each party access to a shared, trusted record and a "single source of truth" previously impossible to achieve across organizations. Step 11 in the new model thus ensures the customer is immediately updated and equipped with all information and evidence of the completed delivery, and all participant's obligations are closed out automatically. The process ends not with a pile of paper, but with an immutable digital trail of the transaction accessible to all stakeholders with the necessary permissions.

5.3. Comparison of Traditional vs. Blockchain-Integrated Process

The following table summarizes the key differences at each step between the traditional logistics process the traditional logistics process in Armenian companies and the blockchain-enhanced model (table 2).

Tabel 2. Comparison of each step before and after integrating blockchain and smart contracts in logistics

Process Step	Traditional Logistics (Pre-Blockchain) in the companies	Blockchain-Integrated Logistics (Post-Integration)
1. Freight Request Receipt	Customer request via email/phone to a single party. Manual logging of request details.	Customer submits request on a blockchain platform (DApp). Request is immutably recorded and instantly visible to all relevant parties.
2. Data Integrity Check	Sales rep. manually verifies all required data is present; must follow up with customer for missing info.	Smart contract validates that all required fields are provided. Incomplete requests are automatically flagged/rejected until corrected.
3. Tender to Carriers	Logistics team contacts carriers (emails/calls) one by one or broadcasts request via intermediaries. Time-consuming coordination.	Request is automatically shared with authorized carriers on the blockchain network. All eligible carriers see the tender simultaneously, enabling faster response.
4. Receiving Price Offers	Carriers send quotes back via email/phone. Logistics staff manually compiles and compares offers. Data	Carriers submit bids as transactions on blockchain. Offers are logged transparently and can be automatically aggregated by the

	silos and potential for error in transcription.	system. No manual re-entry; tamper-proof record of all bids for fair comparison.
Process Step	**Traditional Logistics (Pre-Blockchain) in the companies**	**Blockchain-Integrated Logistics (Post-Integration)**
6. Documentation	Physical or PDF contracts signed with new partners. Freight order document created and stored in each party's system. Potential duplicate records and delays in exchanging documents.	Smart contract itself contains the agreed terms. All documents (contracts, permits, etc.) are uploaded or hashed on the blockchain for shared access. A single, synchronized version of documentation exists for all parties, ensuring consistency.
7. Payment	Customer pays via traditional means (bank transfer, etc.), possibly in advance or on receipt. Carrier invoiced and paid separately. Process involves reconciliation and trust that payment will be made.	Payment is automated by smart contract. Funds can be held in escrow and released upon delivery or milestones. No separate invoicing step – the blockchain triggers payment when conditions (delivery, inspection) are met, reducing delays.
8. Insurance	Cargo insurance arranged through emails/portals with insurer. Paper policy issued. Claims (if any) handled after-the-fact, with lengthy assessments.	Insurance policy info stored on blockchain for transparency. Smart contracts enable parametric insurance – automatic payout if conditions (damage, delay) occur, using trusted sensor data. Faster claims and reduced paperwork in risk management.
9. Shipment Prep & Verification	Logistics coordinators chase missing documents from supplier. Must manually verify compliance with requirements and documentation completeness. Errors or omissions can cause last-minute delays.	Blockchain checklist ensures all required docs are submitted (hashes on ledger). Missing items trigger automatic alerts. All parties verify documents on the shared ledger, and smart contracts ensure conditions (e.g. regulatory certificates) are met before dispatch.
10. Transportation Tracking	Relies on periodic manual updates via calls/emails. Limited real-time tracking: data often delayed and siloed. Hard to detect issues	Continuous real-time tracking via IoT devices logging to blockchain. All stakeholders have live visibility into shipment location and condition. Smart contracts can trigger alerts or

	promptly; trust needed in carrier communications.	actions on delays or deviations. Immutable, shared data builds trust in shipment status.
Process Step	**Traditional Logistics (Pre-Blockchain) in the companies**	**Blockchain-Integrated Logistics (Post-Integration)**
11. Delivery & Final Docs	Delivery confirmation is communicated to customer. Physical delivery receipts and final documents are sent to customer and archived by each party. Potential for lost paperwork or disputes over document integrity.	Delivery event recorded on blockchain (e.g. digital POD). Customer and all parties automatically receive confirmation. Final documents (invoice, etc.) are already on ledger, accessible immediately. The entire transaction history is archived immutably on-chain as a single source of truth.
12. Process Close-Out	Logistics provider sends thank-you notes, closes internal files, and archives records. Each party keeps its own records of the shipment's lifecycle.	Network automatically logs completion for all parties. Thank-you messages or feedback requests can be auto-triggered. The blockchain ledger is the archive, providing a permanent, secure record of the shipment for all stakeholders, without separate reconciliation.

After comparing traditional and blockchain-based logistics models and identifying the advantages, it is important to outline a realistic transition path. The following roadmap suggests a structured sequence of actions that Armenian logistics companies can implement to integrate blockchain technology into their operations, ensuring the effective application of the steps discussed earlier. In our work, the process assumes that all actors, including customers, shippers, brokers, and insurance agents, are already registered on the blockchain-based logistics platform. Their profiles are verified during registration, and their permission levels are set based on their roles (depending on the company's requirements). And everyone has agreed to the public oferta. This allows the process to start from the moment a shipment request is initiated, without additional identity verification steps.

5.4. Proposed Roadmap for Blockchain Integration in Armenian Logistics Companies

The roadmap should reflect the strategic goals of transparency, automation, and increased efficiency, as well as the operational reality, and outline the means to achieve them. The following six-phase framework outlines the key steps to implement the blockchain-based logistics process model proposed in our study.

Phase 1: Internal Process Assessment

The first step involves comprehensively assessing the company's existing logistics operations. This involves identifying repetitive, manual tasks, reliance on paper documents, delays in information flows, and the frequency of data inconsistencies within the company, internally and externally. The goal is to understand the current performance baseline and identify the most disruptive gaps that can be addressed through blockchain technology.

Phase 2: Evaluation of Digital Readiness

After conducting the assessment, the company is recommended to perform a digital infrastructure and capabilities assessment. This phase includes obtaining a clear picture of the availability of the necessary hardware and existing software, access to a secure internet connection, the presence of internal ERP or warehouse systems, and the willingness of staff to work with digital tools. A gap analysis here can help prioritize investment application areas for review before implementing blockchain. This also includes determining whether the company needs to acquire technical assets such as Internet of Things (IoT) devices, RFID scanners, cloud infrastructure, or secure data management tools to enable their integration with blockchain-based logistics workflows.

Phase 3: Pilot Application on a Selected Process

Before a full deployment, it is recommended to implement a partial deployment as a pilot program. Implementing blockchain on one or more pre-selected processes allows for evaluating its results and feasibility. For example, a pilot project on delivery tracking, document verification, or brilliant contract execution can be implemented for a limited number of transactions, for an initial assessment of effectiveness for a specific company. This will allow the company to understand the operational impact, test integration with existing systems, and solve problems that may seem unexpected at first glance on a small scale.

Phase 4: Internal Training and Change Management

It should not be forgotten that a successful implementation requires employee capacity building and engagement. At this stage, the company's teams should undergo structured training on the blockchain platform, its functions, and the expected benefits. In addition, top management should promote innovation and implement a culture that supports digital transformation, proactively addressing resistance to change.

Phase 5: Selection of Technical Solution and Partners

Once the pilot phase has demonstrated its viability, the organization should choose which blockchain platform to deploy (e.g., permissioned or consortium-based), determine the contents of the smart contracts, and consider the sensitivity of company-specific data, scalability, and compatibility with Armenian regulatory conditions. Strategic consultations with technology providers and logistics IT consultants may be necessary to ensure a robust and sustainable investment.

Phase 6: Gradual Rollout and Performance Monitoring

The final phase involves gradually expanding the blockchain system to include all relevant logistics functions that solve the company's problems in phases. This step-by-step implementation should be accompanied by continuous monitoring of key performance indicators (KPIs), such as process speed, customer satisfaction, error reduction, and other important indicators for the company. Feedback loops should be established to adjust the system and operational workflows.

By following this roadmap, Armenian logistics companies can take a structured and strategic approach to blockchain integration, reducing the risks of investment failure and maximizing long-term benefits. Rather than attempting a complete transformation all at once, our proposed phased model promotes gradual adaptation, internal capacity building, and performance monitoring, enabling organizations to assess each implementation phase's efficiency (or coefficient of performance).

This six-phase roadmap essentially incorporates best practices outlined in the core logistics literature. For example, the initial assessment and phases are consistent with the recommendations of Christopher (2016) and Rushton et al. (2017) on infrastructure planning and performance benchmarking. The phased implementation and change management section can also be found in Mangan et al., (2020) guide on digital transformation in global supply chains. After all, the roadmap offers a practical path to move from current inefficiencies to a transparent, secure, and future-proof logistics system that aligns with international best practices. While specific investment amounts will vary depending on the company's size, technological maturity, and scope of implementation, organizations should anticipate the costs associated with upgrading digital infrastructure, acquiring IoT and hardware, system integration, and workforce training. Therefore, a preliminary cost-benefit analysis is recommended during the evaluation phase to assess the financial viability and expected return on investment (ROI) associated with blockchain integration. As the co-founder of Onex, one of Armenia's leading logistics solutions companies, noted, currently the use of new technologies in business is not a luxury, but a necessity.

5.5. Cultural Factor and Trust Considerations in Blockchain-Enabled Logistics

Implementing a blockchain-based logistics model is a technical upgrade and a socio-cultural transformation for Armenian organizations and people involved. The proposed transparency and automation will alter how stakeholders interact and trust each other. Despite the ongoing digitalization, two critical human factors must be addressed: a) organizational culture, b) inter-organizational trust.

5.5.1. People and Culture

Even the most advanced technology will falter without a supportive organizational culture. In the context of knowledge sharing and process innovation, it has been observed that people and culture are at the heart of creating a successful knowledge-based organization (Mårtensson, 2000). This insight underlines that employees and partners must embrace a) open information sharing, b) continuous learning for a blockchain system to deliver its full value. In a traditional logistics firm, employees might be used to siloed information and manual control. Shifting to a blockchain means embracing transparency, data sharing, and collaboration across departments and companies. Such a shift can be challenging if the culture is not ready. It also requires change management – training staff to work with shared dashboards, trust data from automated systems, and collaborate more closely with external partners in real time. On a broader scale, successful blockchain consortia in supply chains often hinge on competitors or diverse actors working together; this collaboration requires knowledge sharing among supply chain partners, which is fundamental to blockchain adoption (Zhang et al., 2024). Companies must cultivate a culture of openness and teamwork over finger-pointing or protectionism. This might mean redefining KPIs to reward collective success (like end-to-end fulfillment speed) rather than individual department efficiency. It also involves educating all participants about the technology to alleviate fears and build competence. When people understand how the blockchain ensures integrity, they are more likely to trust and use it. Essentially, the technology provides the platform for a "knowledge-based organization" in logistics, but leadership and management culture must encourage people to use that platform effectively, breaking down old silos.

5.5.2. Trust in a "Trustless" System

Blockchain is often touted as creating a "trustless" system, meaning parties don't have to trust each other personally; they trust the ledger and code. That is only a partially correct statement. In a logistics network where participants may not fully trust one another (e.g., new partners or historically adversarial relationships between shippers and carriers), having an immutable record can reduce the need to trust someone's word unquestioningly. However, in practice, blockchain reconfigures trust rather than eliminating it. Participants must trust the system's correctness and the governance of the blockchain network. There is also a need for trust in the data inputs – IoT devices and humans must report honestly for the blockchain record to reflect reality. Recent research (Brookbanks & Parry, 2022) has noted that blockchain being completely "trustless" can be a myth; implementing blockchain does not automatically erase the need for trust among people. Instead, it shifts some trust to technology and demands new forms of trust: trust in the code and the consortium or platform operator (for permissioned chains). Moreover, relationships still matter. A smart contract might handle known contingencies, but stakeholders must rely on interpersonal trust to negotiate a solution when an unforeseen event that isn't coded in the contract occurs. This means that the code of the proposed system remains open to ongoing enhancement. During our surveys, companies also noted that logistics is the art of navigating and working under pressure, which is very specific to Armenians. Thus, trust and blockchain work in tandem: the blockchain provides a baseline of reliable, shared information (so parties can trust the data), and this allows a higher level of trust to develop between organizations, since there is less fear of opportunistic behavior or data manipulation. Over time, as companies collaborate through the blockchain network, a culture of "trust but verify" emerges – participants trust that the system will enforce the rules without double standards and trust each other more because the system mitigates the worst risks of cheating.

It’s important to note that introducing blockchain can also change power dynamics and trust relationships. For example, suppose a freight forwarder’s value was previously seen as an information gatekeeper (coordinating and keeping records). In that case, the role changes to being an information steward on a shared platform. Some parties may fear losing control or hesitate to share data (a cultural barrier). Building trust in the network’s governance (how data can be used, who owns the data, and how decisions are made on the blockchain platform) is essential. Clear agreements and possibly a neutral consortium governance model can help allay these concerns.

Additionally, early successes and transparency about the benefits can help win hearts and minds. When employees see blockchain automation spare them tedious tasks, reduce errors, and relieve them from interpersonal tensions, they trust the system. When carriers know they get paid faster and disputes vanish, they trust the platform and the lead organization more. Trust evolves from primarily interpersonal to increasingly institutional and technology–embedded in the processes and code. Yet, human trust doesn’t disappear: it underpins the willingness to collaborate and adapt when the code doesn’t cover everything.

In conclusion, aligning the culture with the new technology is as important as the technology itself. Ensuring that people are on board – trained, informed, and motivated – and that trust is maintained (in new forms) across the network will determine the long-term success of a blockchain-integrated logistics model. As much as blockchain provides a foundation of transparency and security, the adage holds true: technology is an enabler, but people drive the change. Fostering this culture that values transparency and cooperation and recognizing that trust is a glue that “holds people together in periods of uncertainty” (Scott & Walsham, 2005) even when smart contracts are in place, will create a network that is both technologically robust and humanly resilient.

Conclusion, Limitations, and Directions for Future Research

In the current context of a dynamic global market economy, where technological advancement is accelerating across the logistics industry, Armenia has yet to adopt essential tools such as blockchain and smart contracts to align with global tectonic shifts. To improve the current economic situation of post-Soviet Armenia, there is an urgent need for the application of modern and flexible instruments grounded in contemporary and more effective scientific approaches to business management. This study - built upon a combination of global best practices, local needs assessment, and a qualitative methodology - represents one of the initial steps toward digitization and innovation within Armenia's logistics system.

Throughout the research, it became evident that Armenia's current logistics framework is predominantly based on traditional methods, relying heavily on manual work and suffering from a lack of transparency. The system faces challenges including sluggish operations, inefficient information flow, paper-based documentation, and trust-related issues. In this context, blockchain technology and smart contracts emerge as transformative tools that can enhance transparency, reliability, and operational speed while reducing human error and redirecting saved time and resources toward business development.

- The proposed 11 - step blockchain-integrated logistics model fully transforms the traditional freight transport process in Armenia - from the initial cargo request to final delivery. Each phase is enhanced through automation, unified registration systems, and smart contracts. Manual and repetitive actions (data entry, status updates, document exchange, payment execution) are minimized or fully replaced by code-driven workflows that are faster and less error-prone. This leads to significantly improved efficiency and reduced delays. For example, real-time data exchange shortens update lags, and automated payments accelerate cash flow cycles.
- A comparative analysis was conducted between traditional and blockchain-based models. The study includes a detailed comparison table showing how each problematic area in the traditional model is addressed: duplicate data entry is replaced by unified input, slow communication by instant notifications, opacity by real-time tracking, and potential disputes by preventive encoded rules.
- The technical aspects of blockchain and smart contracts - although rooted in the programming domain - were also individually analyzed based on the input of logistics managers and order specifications.

This modernization does not eliminate the human role; on the contrary, it elevates it by allowing professionals to focus on exception handling, customer service, and strategic planning, while routine transactions are managed by the system. Employees are thus freed from bureaucratic tasks to concentrate on higher-value functions, making organizations more agile and responsive.

Given that many key stakeholders - including employees, industry representatives, and business leaders - often lack sufficient awareness or readiness to adopt innovative technologies, the following actions are recommended:

- Incorporate training and institutional support components to ensure successful implementation of the model;
- Consider this toolkit as a platform for a “knowledge-based organization” in logistics, with a new corporate culture that encourages people to make full use of it.

The study draws on international best practices, including real-world examples such as the TradeLens platform and other initiatives, to demonstrate both the potential and the systemic commitment required for blockchain success in logistics.

We reiterate: technology alone is not a magical solution. Success requires: a) change management, b) a culture of trust and knowledge sharing, and c) phased implementation - suggested in the form of a roadmap. Challenges such as legacy system compatibility and scalability must be acknowledged, yet they are surmountable given blockchain’s rapid evolution and emerging standards. In fact, blockchain is now capable of integrating with IoT and artificial intelligence, enabling even more intelligent supply chains.

Certain segments of the industry still express skepticism toward blockchain, primarily due to lack of experience and regulatory uncertainty. This research addresses these concerns by offering an approach grounded in expert insights and practical examples to build trust.

Based on identified gaps in companies, the proposed roadmap enables organizations to assess their readiness, identify necessary resources, and pursue a guided and feasible technological transition. The model promotes alignment with international standards, potentially enhancing the global credibility of Armenian logistics companies.

Digital technologies - especially blockchain - can be viable and effective even in smaller and developing markets, provided that implementation follows the right strategy. Interviews conducted confirm local market interest and a moderate level of readiness for transition to more digitalized systems.

This research provides:

- **Theoretical value** by offering a structured approach that integrates technological, strategic, and organizational elements;
- **Practical value** as a roadmap for Armenian logistics companies—from strategic planning to operational execution;
- **Policy-level value** by serving as an impetus for potential state support or facilitative regulatory changes in the logistics sector.

However, the thesis is subject to several notable limitations:

- It does not include statistical testing or econometric modeling, which limits the quantitative reliability and generalizability of the results.
- The number of interviews conducted is limited, which may affect the comprehensiveness of the conclusions.
- No financial analysis was conducted due to the inability to examine a specific company case.
- Some legal and technical assessments remain at a general level due to space constraints typical of a master's thesis, leaving room for future in-depth exploration.

Future research directions may include:

- Implementing pilot programs within logistics companies of varying sizes to test the practical applicability and efficiency of the model;
- Deepening the study of blockchain regulatory frameworks to identify legal amendments required in Armenia;
- Developing software solutions for the proposed platform, including user access and interface phases;
- Integrating smart contracts with AI tools for automated data analysis and decision-making;
- Evaluating the model's applicability to other emerging markets, including the South Caucasus and Eastern Europe.

In conclusion, this thesis offers Armenian logistics companies a future-ready model that enhances efficiency, transparency, and trust. It addresses long-standing inefficiencies in the traditional model and aligns with the global trend toward real-time information flow and digital transformation. Through this synergy, the logistics sector in Armenia can achieve new levels of performance and credibility, harnessing the potential promised by emerging technologies within global trade networks. Nevertheless, the existing limitations of this study call for continued research to present the subject more comprehensively.

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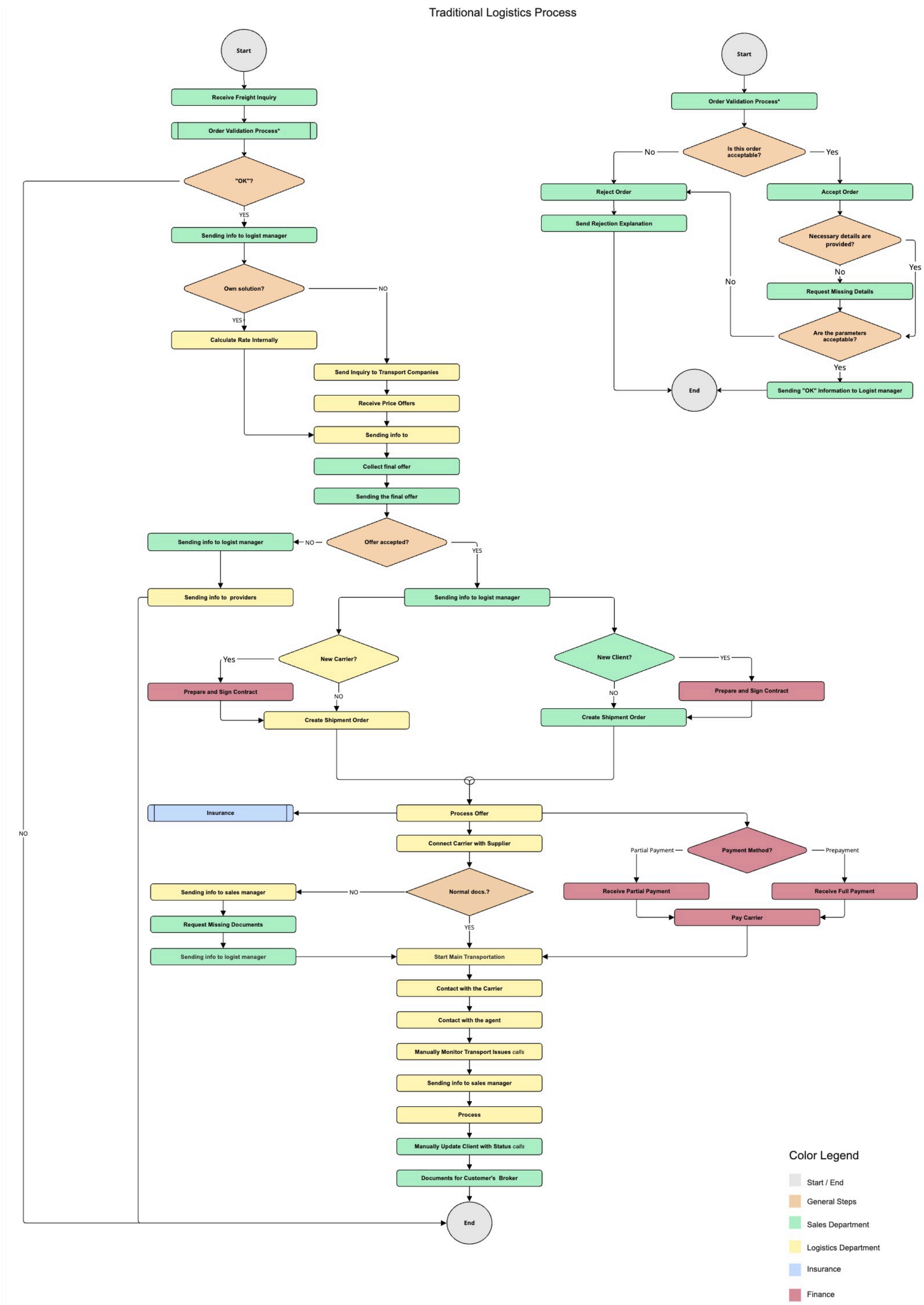
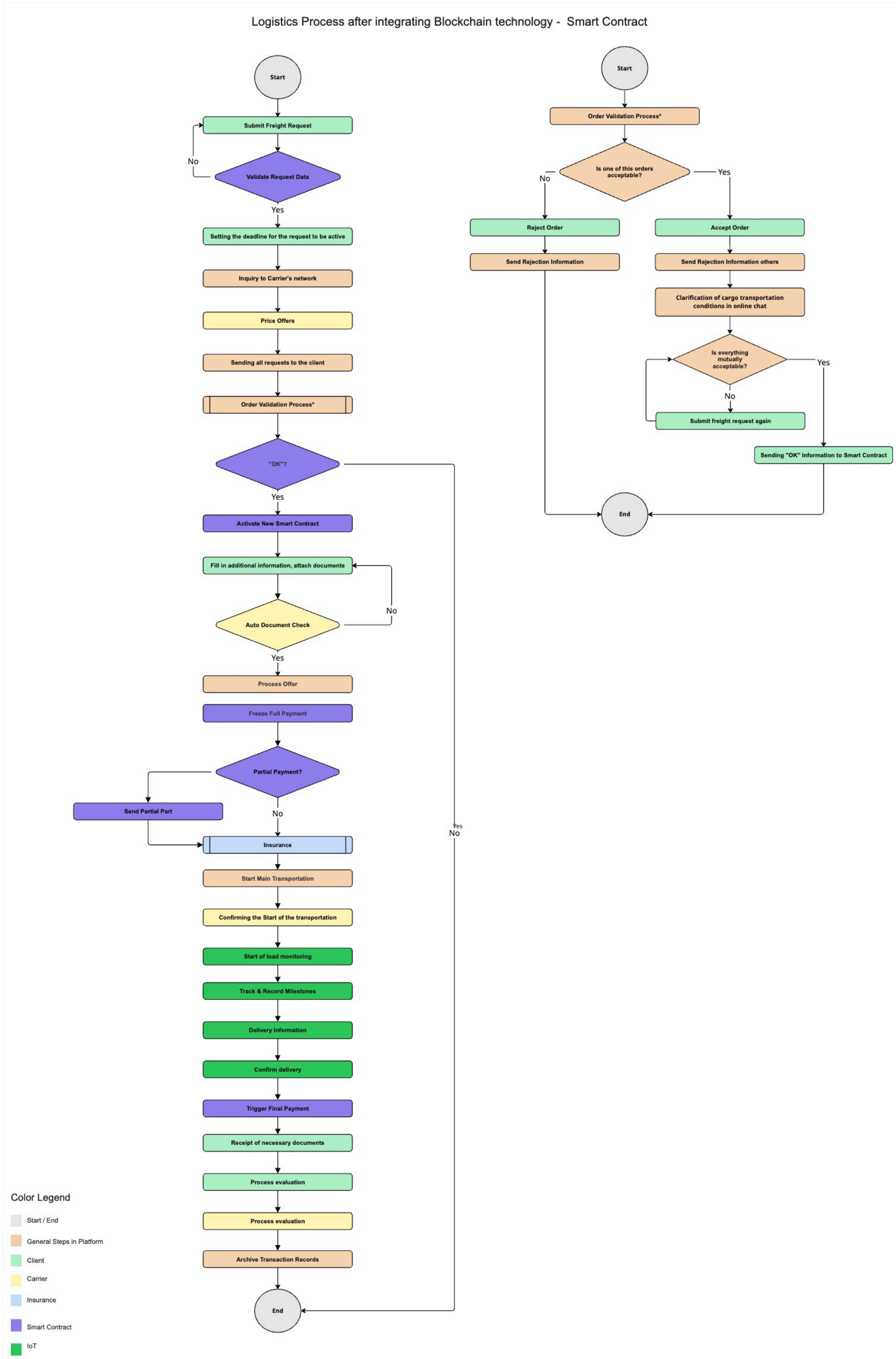
Appendix

Appendix A



Appendix B



Logistics Process after integrating Blockchain technology - Smart Contract
Start
Submit Freight Request
Validate Request Data
No
Yes
Setting the deadline for the request to be active
Inquiry to Carrier's network
Price Offers
Sending all requests to the client
Order Validation Process*
"OK"?
Yes
Activate New Smart Contract
Fill in additional information, attach documents
Auto Document Check
No
Yes
Process Offer
Freeze Full Payment
Partial Payment?
Send Partial Part
No
Insurance
Start Main Transportation
Confirming the Start of the transportation
Start of load monitoring
Track & Record Milestones
Delivery Information
Confirm delivery
Trigger Final Payment
Receipt of necessary documents
Process evaluation
Process evaluation
Archive Transaction Records
End
Yes
No
Start
Order Validation Process*
Is one of this orders acceptable?
No
Yes
Reject Order
Accept Order
Send Rejection Information
Send Rejection Information others
Clarification of cargo transportation conditions in online chat
Is everything mutually acceptable?
Yes
No
Submit freight request again
Sending "OK" Information to Smart Contract
End
Color Legend
Start / End
General Steps in Platform
Client
Carrier
Insurance
Smart Contract
IoT

Appendix C

Dear [XXX] Team,

As part of my master's thesis, I am studying the traditional logistics model currently used in Armenia and comparing it with modern blockchain-integrated solutions. To support this research, it is essential to learn from the experience of leading companies in the field.

I kindly ask you, if possible, to respond to the following questions based on your organization's current practices:

1. Company Overview

2. Company Vision

Please confirm or suggest adjustments to the following stages your company goes through when receiving a transportation request:

1. Receipt of the request via email or phone
2. Review of the request; if information is missing, a follow-up call or email is made
3. Sending the request to partner companies
4. Collection of pricing offers
5. Submission of a price offer to the client
6. If the client agrees and is new, contract signing followed by issuing the transport order
7. Payment stage (as defined in the contract or transport order – e.g., 100% before shipment, 50-50, or other arrangements)
8. Cargo insurance
9. Pre-check of documentation required for transportation
10. Execution of transport (with ongoing updates via phone/email from the pickup location)
11. Notification of delivery and issuing the final invoice

Questions:

1. Does your company use digital platforms to find and hire freight carriers? If yes, which ones?
2. What measures does your company take to ensure the security of hiring carriers (e.g., credit checks, background verification)?
3. How do clients usually submit freight requests—by email, phone, or other methods? Are the received data manually entered into other systems?

4. How often do you encounter issues where the client provides incomplete or incorrect shipment details, requiring you to follow up?
5. How much time is typically needed to forward the request to your carrier partners? Do you use phone calls, email, or a centralized system?
6. How do you receive pricing offers from carriers, and how long does it take to compare them and present a final offer to the client?
7. Based on your experience, how complex and time-consuming is the process of drafting and signing the freight agreement?
8. Does your company use digital contracts with electronic signatures for agreements with clients or freight carriers?
9. How do you track shipments during transport? Can the client monitor the shipment in real time, or are updates shared manually?

Artificial intelligence (AI) and blockchain technologies are transforming logistics - from route optimization to demand forecasting.

1. Does your company currently use digital solutions?
2. How are these applied - for example, to optimize delivery routes, reduce transport costs, or assess automation levels in your fleet?
3. Is your company familiar with blockchain technology? If so, is it used to improve traceability, ensure data security, or enhance the efficiency and speed of contract management? If not, why?
4. Is your company familiar with smart contracts? If yes, are they used to make processes faster and more transparent? If not, why?

Thank you in advance for your time and cooperation. Your insights will significantly contribute to the credibility and quality of my research.

Best regards,

Tatev Harutyunyan

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