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Iran's Railway Supply Chain Problems: Blockchain Solutions and Implementation Challenges

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Master Thesis submitted in fulfillment of the Degree

Master of Science in Management

Submitted to Professor Horst Treiblmaier

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AFFIDAVIT

I hereby affirm that this Master's Thesis represents my own written work and that I have used no sources and aids other than those indicated. All passages quoted from publications or paraphrased from these sources are properly cited and attributed.

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ABSTRACT

The focus of this master's thesis is a detailed qualitative examination into the numerous problems plaguing the supply chain within Iran's railway industry. The study aims to not only identify the current concerns but also investigate the possibilities of blockchain technology to address these problems. It does this by drawing on in-depth interviews with 15 specialists and managers who are deeply ingrained in the intricate workings of the Iranian railway supply chain. The study broadens its scope to assess the particular barriers preventing the adoption of blockchain technology in Iran, a country dealing with unusual economic circumstances. The study also explores methods for influencing stakeholders and encouraging the broad adoption of blockchain technologies in this sector.

This thesis' supporting literature evaluation has been constructed to offer a strong theoretical framework. It carefully considers particular characteristics of blockchain that are highly pertinent to the setting of the Iranian railway supply chain. Transparency, traceability, security, and efficiency are included in these qualities. The review also carefully examines the numerous uses of blockchain technology, with a focus on how it can support smart contracts, improve project management, promote supply chain sustainability, and, most importantly, guarantee product traceability. These elements together offer an intellectual framework for understanding the blockchain technology's disruptive potential within Iran's railway supply chain.

In this research a wide range of difficulties experienced by the Iranian railway supply chain through the voices of industry professionals, including problems with documentation's opacity, the tracking of goods, the security of transactions, and the improvement of overall operating efficiency are learned. The interviews unmistakably demonstrate that blockchain technology has the capacity to fully address many of these issues. Blockchain adoption in Iran is not without its unique and serious challenges, including complex regulatory issues and unpredictability in the economy.These include methods for fostering relationships with stakeholders, sharing information, and deftly navigating Iran's complex socioeconomic environment.

In conclusion, this master's thesis significantly advances our knowledge of how blockchain technology might transform the Iranian railway supply chain. It clarifies the obstacles preventing progress while also highlighting the potential advantages of utilizing blockchain technology. It also provides a plan for overcoming them and energizing support for blockchain adoption. The ramifications of this research go beyond the railway industry, providing insightful information for businesses facing comparable problems in areas with unusual economic situations. In the end, this study establishes the framework for an Iranian railway supply chain that is more effective, secure, and prepared for sustained growth.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

BC: Blockchain

SC: Supply Chain

SCM: Supply Chain Management

SSCM: Sustainable Supply Chain

RFID: Radio Frequency IDentification

IoT: Internet of Things

AI: Artificial Intelligence

POMS: Product Ownership Management System

JSON: Java Script Object Notation

API: Application Programming Interface

R&D: Research and Design

KPI: Key Performance Indicator

ITS: Intelligent Transportation System

UITS: Urban Intelligent Transportation System

IQR: Inventory Quality Ratio

SCA: Supply Chain AActors

CBI: Central Bank of Iran

1 INTRODUCTION

The journy of the railway industry in Iran began in 1927 in the early Pahlavi period and continues to expand until now. Given the vast geographical area of Iran, this industry plays an important role in connecting people as well as transporting goods across the country by forming the backbone of transportation networks. However, this industry in Iran, especially after the Islamic Revolution in 1979, has faced many problems and witnessed the lack of proper use of potentials. Before the Islamic Revolution, 4,676 kilometers of railway lines were built, while after the Islamic Revolution, this figure reached 5,495 kilometers until 2013. Given the drastic advances in technology, experts in this field believe that the advances made are less than expected (Tin.ir, 2015)

This master's thesis seeks to identify the issues that hinder these developments and impede the industry from reaching the point where it can fulfill its potential. One of the areas that is really critical in this industry is the supply chain. Therefore, the aim is to find these problems and challenges that have rarely been investigated and discussed in the literature before, although for the activists of this field, there are obviously such challenges that prevent the proper functioning of the supply chain and the impacts of these challenges and problems can be mitigated through taking appeopriate steps.

Every industry has difficulties and challenges and in light of its significance in Transportation and development of the countries, the railway industry is one of the infrastructure industries that need to be focused on in order to find solutions to improve it. Certainly, there are many aspects and areas where technological advances can help alleviate problems, and of course, there are many obstacles in use of new technologies in practice. As a brand new tool, blockchains are starting to be implemented as a disruptive technology in various industries. Despite this fact, there are few investigations about the potential use of the technology in the rail industry. (Preece, 2020). According to Dietrich et al. (2021), among the 43 publications that have the quality criteria of having detailed concepts in the field of blockchain applications in supply chain management by 2019, only 2 researches belong to transportation area, while 22 researches are done on food industry , 8 researches on automobile/production, and 5 researches on health care. Although this lack of proper resources makes the work very hard, but knowing the potentials of blockchain technology is encouraging to delve into the topic and explore more about it in this research.

Supply chain is consistently adopting new advancements such as big data, industry 4.0, IoT and blockchain automating the existing standards of this industry, called as Cloud Chain (Pattnayak & Patnaik, 2022). Blockchain optimizes the processes and brings transparency to the supply chain. Information from when items are ordered to when they are delivered is transparently available within the chain and this data is easily verifiable (Rathore, 2023). This research is trying

to figure out the specific ways in which blockchain can restructure the supply chain of railway industry in Iran and how it can help this industry to overcome its problems and challenges. Nevertheless, there are obstacles and hurdels to implementing this technology, particularly in Iran, which struggles with economic issues and is not yet prepared to welcome novel ideas and new tools. Railway industry is one of those sectors which suffers more than many others from difficulties in implementing new technologies. By identifying the obstacles, the research aims to investigate the feasibility of using this technology in railway sector.

In conclusion, this master's thesis embarks on a multidimensional journey from finding existing problems in supply chain of railway industry to identifying the remedies that blockchain technology brings to this chain as well as the obstacles of implementing this new concept in this section. This research can shed a light on the pathway of those researchers and activists who intend to take actions futurewise to address the problems of this industry in Iran through implementing blockchain.

Research Questions:

Compared to road transport, railway transport in Iran is more advantagous and has the potential to solve a large part of conveyance problems. This type of transportation is more cost-effective than road transportation inside Iran due to the reduction of required fuel, minimization of environmental pollutions, as well as lessening the road and highway repair costs (Tamannaei & Dehshiriparizi, 2017). Despite its importance, there are many problems and challenges in different areas within this industry, which makes this industry not progress enough. One of these areas is the supply chain, which engages multiple stakeholders and continues to operate based on conventional business processes, lagging behind in implementing technological transformations.

The blockchain paradigm has brought various solutions to the supply chain. It has the potential to transform SCM through its attributes of transparency, credibility, reliability and security, cost reduction, direct transactions, streamlined operations and minimized wastage(Gurtu & Johny, 2019; Philipp et al., 2019). Blockchain's solution to streamline processes and operations and overcome existing challenges is an enticing proposition for alleviating difficulties in the railway supply chain.

However, while the use of blockchain in this industry seems very promising, not only is there very little practical work in this area, but the amount of research done in this area is also very rare. To successfully use blockchain, we must first recognize the problems, then find out how blockchain can solve these problems and what are the obstacles to its implementation, as well as the solutions to these obstacles. In the end we have to convince the stakeholders of a supply chain to approach the use of this technology. All these steps are done only if sufficient research

has been done in this area and instructions have been provided. This master's thesis tries to fill this research gap by conducting a holistic research based on the experiences of activists in this field and secondary sources mainly on an international scale.

This master's thesis attempts to investigate the possibility of integration of blockchain technology in order to address the existing problems of the supply chain of the railway industry in Iran. The research is built upon the following key research questions, which together pave the way for a comprehensive examination of the existing problems and challenges, application possibilities, and practicality of blockchain adoption within this context:

Question1: What specific problems/challenges within the supply chain of the Iranian railway industry hinder operational efficiency and inhibit effective resource utilization?

Question2: What are the applications of blockchain technology in solving these problems and increasing the efficiency of the supply chain?

Question3: What are the main infrastructural, technical, and regulatory barriers that hinder the adoption of this technology in the context of the Iranian railway supply chain?

Question4: How to introduce the potential benefits of integrating blockchain technology into the Iranian railway supply chain and mitigate its implementation barriers?

2 LITERATURE REVIEW

The beginning of the 21st century coincided with the fourth industrial revolution, which changed the course of the industrial paradigm and at the same time changed the social, political and economic conditions. State of the art technologies such as artificial intelligence, blockchain and advanced mobile networks are the drivers of this digital transformation. For example, blockchain technology provides a platform on which digital, biological and physical elements converge in the fourth industrial revolution (Mehrbani, 2022).

Blockchain is one of those technologies that has become popular recently and its application can be seen in various industries, one of which is e-commerce platforms such as Amazon. Blockchain provides a distributed ledger for the supply chain of these industries where data is immutable once it enters the chain (Zanardo, 2023). The focus of research on blockchain however has been on its application as cryptocurrencies such as Bitcoin, and not enough research has been done in other sectors and environments (Kitsantas & Chytis, 2019).

In a research conducted on the most influential contribution of the blockchain in the two fields of supply chain and logistics, and road traffic management and smart cities, it was found that blockchain has a long way to reach its peak, but at the same time, it has great potential Considering its impact in several areas such as food tracking and tracing, regulatory compliance, smart car security and supply-demand matching. Due to the fact that several models have been recently discussed in theory, while very few of them have been implemented in practice within the contexts, there is still a lot of work to be done before blockchain technology matures (Astarita et al., 2020).

The purpose of this research is to investigate the possibility of using blockchain technology to address these problems in supply chain of a specific industry which is railway industry in Iran. It deals with uncovering the existing problems related to the supply chain, finding the solutions that blockchain offers, and investigating usability issues. For a better understanding of the topic, a general understanding of blockchain technology and its applications in the supply chain field is reviewed.

2.1 Fundamentals of Blockchain

2.1.1 Definition

Blockchain is a digital platform built on a peer-to-peer network which is decentralized. All nodes are interconnected using predefined protocols and the data shared on this platform is approved by all the nodes (CFTE, 2023). The evolving blockchain technology that has been implemented so far is divided into three generations. The first generation eliminates the role of middlemen in transactions by using Bitcoin as a digital currency, the second generation supports new use cases

(Ethereum) using smart contracts, the third generation (Cardano, Avalanche, Tron) is dealing with improving scalability and enabling vast transactions. The evolving fourth coming generation is created to use AI or perhaps focus on mass adoption, leading to better penetration of blockchain into everyday life (The Nation, 2022).

Blockchain has some main features, one of which is decentralization, through which all connected users have access to the entire data and can verify this data. There would be no central part which controls the transactions between the nodes. Although the applicants are able to remain anonymous, the communications between users can bee seen by all the members. The records cannot be changed once they are registered and they are chronologically ordered. Also, a mathematical logic can be implemented to define the transactions between the nodes (Iansiti & Lakhani, 2017). Although blockchain was introduced in 2009, it started to gain popularity in 2015 when non-financial companies such as Goldman Sachs, Barclays, J.P. Morgan, etc. approached to design a blockchain-based platform on which they do their financial transactions (Morwani & Mandalia, 2020). Blockchain can be defined academically as below:

"A digital, decentralized, and distributed ledger in which transactions are logged and added in chronological order to create permanent and tamper-proof records" (Treiblmaier, 2018).

2.1.2 How blockchain works

Blockchain is a shared, distributed and open ledger for storing data whose transaction is supported by a cryptographic value (Choi, 2020) in a peer-to-peer network (Chang et al., 2019). Once data is recorded in blocks, they can only be changed with the consent of all/majority users and by changing previous records. This feature makes blockchain a reliable platform for doing business (Dutta et al., 2020).

Dutta et al. (2020) describes the blockchain mechanism as follows. A 256-bit hash number is assigned to each block in the chain, which is created by a scientific algorithm and with the consent of the parties. In a reliable and independent chain, each block is connected to the previous block by referencing the previous hash number. These blocks are added to the chain after being proven through a proof-of-work process called "blockchain mining". After validation, the block enters the auditable and immutable blockchain. Blockchain also has the ability to defend itself internally. More precisely, if detected as malicious, it is detected and defended against, and the infected note is then corrected.

Figure 1 shows the structure of the blockchain. Hash number which is the identification of the block is uniquely allocated to each block and a set of timestamps of recent transaction makes the manipulation of the information impossible (Khatib et al., 2021).

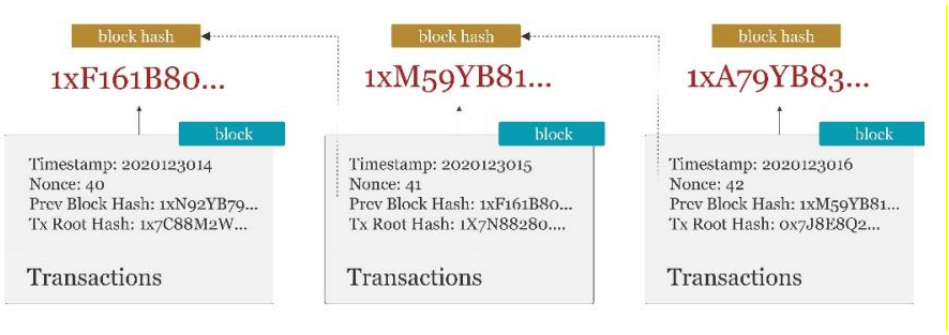


FIGURE 1. BLOCKCHAIN STRUCTURE (KHATIB ET AL., 2021).

2.1.3 Prominent attributes of blockchain

2.1.3.1 Transparency

Blockchain enables transactions to take place based on a distributed trust based on network consensus, rather than based on the explicit trust of a third party. This allows parties to transact directly with each other instead of requiring a centralized intermediary such as banks. By increasing transparency, blockchain can positively impact supply chain performance and lead to greater customer satisfaction and supply chain efficiency (Lee & Zhang, 2023).

Transparency concept aims to say that the information shared on the platform is easily accessible to all members of the chain. Supply chains must provide all the parties with the supply knowledge, normalize the leverage of information during negotiations, and provide more information about the origin of components and processes (Lamming et al., 2001). Organizations strive to monitor upstream activities in the supply chain and make the transfer of information within and outside the organization easier (Frederico et al., 2020).

In the field of supply chain management, transparency and security can be compatible. Confidentiality, which is an aspect of security, imposes limitations on transparency. Blockchains are either permissionless or permissioned. The latter is shared only with a closed group of users to improve privacy (Xu et al., 2016).

2.1.3.2 Security

It is computationally impossible for an attacker to change the data, because the transaction information is secured through the cryptographic algorithm (Sompolinsky & Zohar, 2015). If only valid transactions are added to the ledger, a consensus mechanism is implemented, which ensures the integrity of the network (Bonneau et al., 2015). This mechanism makes the traditional ledgers used so far become immutable ledgers. When someone buys an asset through the plat-

form, the information is stored in the ledger. When someone tries to change the data, all participants will receive an alarm because they are all linked through their previous hash number. This makes it impossible to change the data (Turjo et al., 2021).

By storing the entire blockchain across a large number of nodes and simultaneously verifying transactions and calculating new blocks using miners, data security is further enhanced (Jostock, 2019; Schlatt et al., 2016). Blockchain can modernize the supply chain by providing a secure mechanism for recording data, executing programmed scripts or applications known as smart contracts (Alqahtani et al., 2020). Smart contracts allow supply chain managers to not only trace the origin of products, but also ensure their security (Turjo et al., 2021).

2.1.3.3 Decentralization

To maintain the availability, stability and functionality of a distributed ledger independent of any central authority, we need the blockchain technology (Peter Zhou, 2020). In the traditional centralized transaction model, we rely on a third party that is a centralized authority. It increases the risk of data manipulation. Therefore, there was a need for transform. This transform from a centralized network to a platform shared by all parties where everyone can participate and monitor changes is called decentralization (Bashir, 2018).

The main idea behind decentralization is to distribute the authority and control of transactions among the parties that are connected in the network, removing the single node of authority. In a decentralized platform, there is no need to know or trust other participants, as it provides a trustless network (Pardeshi & Sharada, 2022). All nodes have access to the entire data, which is embodied as a distributed ledger. A ledger cannot be changed without the agreement of all or a majority of nodes. Decentralization also improves data retrieval. The decentralized ledger gives all nodes access to real-time shared data to maintain optimal resource distribution. Decentralization improves security over performance, and this security increases as the number of nodes that become part of the network increases. But it should be noted that as the number of nodes increases, the performance decreases because the nodes have to prove all the new data that is added to the chain (Amazon, 2022). Decentralized ledgers are more resistant to errors, attacks, and collusion than centralized ones (Pardeshi & Sharada, 2022).

2.1.3.4 Efficiency

Blockchain technology is able to improve data integrity and cost efficiency by securing, facilitating and simplifying data-sharing, contracting and financial transactions. Furthermore, the accuracy, security and reliability of the data is improved as manual entry of the data and document processing is not needed anymore after using blockchain technology. As a result, blockchain technology is considered an innovative solution to many problems in various industries and an effective tool to improve processes (Verma, 2023). Many companies such as Walmart and Glencore are motivated to improve their supply chain through the implementation

of blockchain technology and its features (Verma, 2023). These most important features include transparency, consensus mechanism, verifiability, traceability, and security (Crosby et.al, 2016).

As the first and so far the most important application of blockchain that does not require an intermediary company such as a bank or financial institution, Bitcoin plays a fundamental role in transactions between nodes, providing users with decentralized, secure and universal digital cash system. Transactions can be verified in a peer-to-peer network of Bitcoin users built on an immutable public ledger on the blockchain platform (Verma, 2023).

The entire process of SCs has been simplified using blockchain technology. BC has made the complex contracting process between sellers and buyers in a supply chain, cost-effective and resource-efficient. By removing redundant documents, it also removes all complicated and unnecessary burdens from supplier-buyer contracts. To do all these, blockchain has introduced smart contracts. Smart contracts are predefined automatic transactions that are introduced in order to perform and control the flow of documents in contracts. All parties involved in a contract can easily monitor digital documents on the blockchain platform using their electronic signatures (Pournader et al., 2020).

In the future, supply chains will depend on future technologies, one of which is blockchain technology. BC is able to increase the transparency and the adaptability of SC and eliminate intermediaries (Alicke et al., 2017). The result is a faster, more transparent and more agile supply chain that is more cost-effective and competitive for both consumers and producers (Korpela et al., 2017).

2.1.4 Blockchain applications

2.1.4.1 Traceability of goods

The origin of the commodity as well as its sustainability status can be traced and tracked by stakeholders throughout its life cycle using a decentralized ledger (Sadeghi et al., 2022). The risk of prevalence of counterfeits can be reduced by implementing blockchain technology to track the ownership of products. Toyoda et al. (2017) explains that a product ownership management system (POMS) can be used on RFID-tagged items to prevent counterfeiting. Mohit et al have outlined a new BC-based platform for simultaneously preserving privacy, ownership, and traceability. In their proposed framework, the creation of product information (in this case drug) in the chain is done only by the manufacturer. As a result, the seller who wants to sell the counterfeit does not own it. Therefore, the recipient of the goods can refuse to buy. The buyer can always track the product to be sure of the originality of the purchased item (Mohit et al., 2023).

The blockchain-based application developed by (Lavric et al., 2019) for traceability of the products, uses an IoT sensor attached to the consignment which sends signals to Sigfox Gateway. The signals are being sent using UNB of 100 bps and 600 bps (Lavric et al., 2019). The web application then send and receive data to the Sigfox cloud gateway through a lightweight data interface called JSON API (Ashraf & Heavey, 2022).

In today's global markets, supply chains span a large number of countries and involve multiple companies working together. This expansion of supply chains across borders affects business competitiveness as it creates complexity and traceability, making chain maintenance and transparency difficult. Ensuring chain of custody and traceability through BC allows organizations to know the origin, conformity and integrity of the product. This work shows that for a real traceability effect, a more complete approach is to connect supply chain actors (SCA) and identify products using digital certificates. In this regard, a blockchain is used to maintain product traceability and identity validation.

One possible approach to provide traceability in the supply chain is to tokenize products and use smart contracts to track developments (Westerkamp et al., 2020). A strong tracking system helps organizations optimize their inventory, reduce lead times, and improve quality and customer service which leads the companies to be industry leaders in their field of business. A ledger-based blockchain mechanism has been developed to track the ownership of products in inbound and outbound logistics. The results of the implementation of this mechanism prove the improvement of the overall efficiency of the supply chain by increasing the inventory quality ratio (IQR) and reducing the average waiting time in the production line, wholesale and retail points (Ada et al., 2021).

2.1.4.2 Smart Contracts

Szabo (1994) introduced a smart contracts firstly as “a computerized transaction protocol that executes the terms of a contract” (Szabo, 1994). Smart contract provides a platform for two parties that are not mutually trusted to perform transactions reliably without the need for third party verification (Sadiku et al., 2018). Its purpose is to increase the speed of transactions between customers and sellers based on computer codes and logical instructions. The ultimate goal is to provide maximum security that outperforms traditional contract rules while reducing costs. In addition, contracts do not require human intervention, as they are self-executing and become enforceable after the required objectives have been met (Khatib et al., 2021).

Smart contracts extend the blockchain's ability to use data while performing data processing, asset transaction operations, and intelligent asset management (J. Zhang, 2021). They can optimize delivery times for suppliers and also define delivery contract parameters for buyers (Bushuev & Brown, 2022).

Compared to a traditional software solution, smart contracts offer effectiveness, accuracy, accountability, integrity, fraud resistance, uniformity, interoperability, and more. The most outstanding effects of the smart contracts are: self-sufficiency, absence of intermediaries and non-physicality (Rajput et al., 2022). The use of blockchain-based smart contracts in the supply chain has advantages. This assures stakeholders that they not only receive accurate transaction data, but also use a set of pre-defined rules that are known to everyone and are immutable (Rajput et al., 2022). After the implementation of smart contracts, there will be no need for an intermediary such as a bank, because the contracts will be enforceable while all parties participate in the process of confirming transactions. Transactions, all stored in blocks, allow traceability to find the previous owner and ultimately the origin of the product through the timestamp and hash number recorded in each block (Rajput et al., 2022).

Data collected through smart contracts can lead to operational improvements in the supply chain. When mass data is recorded in blocks, it will be easy for customers to do mass customization. Data that tells us, for example, which product generates more revenue or which model is more productive (Casado-Vara et al., 2018; Wang & Wang, 2018). Also, the inventory can be managed more effectively and new products can be designed and produced with this collected information (Cole et al., 2019).

2.1.4.3 Sustainable supply chain

Among other blockchain applications, supply chain sustainability is one of the most prominent (Saberi et al., 2019). Blockchain technology has the capability to optimize upstream (sourcing) phase of the supply chain as well as downstream (distribution) part of it. Technical features of blockchain such as transparency, reliability, integrity etc. help this optimization (Difrancesco et al., 2023). The disruptive technology of blockchain can develop sustainable supply chain management. It can strengthen trust in the credibility of product sustainability by accurately and precisely tracking its flows in the supply chain (Saberi et al., 2019).

Clear and balanced recording of transactions in the ledger reduces the possibility of corruption of all SC participants. In addition, the history of the product in the chain helps to improve the ethical sourcing process. Ultimately, blockchain helps create a healthy, safe and prosperous business environment, thereby protecting human rights throughout the supply chain (Di Vaio & Varriale, 2020; Saberi et al., 2019).

Influenced by long-term fluctuations in global trade, the shipping industry has recently shifted from excess shipping capacity to shortage, both situations seriously hampering the ability of the shipping industry to expand sustainably (F. Zhang & Gu, 2022). Through the knowledge-cycling and relational measures which is one of the applications of blockchain, it supports sustainable business models and promotes sustainable practices in shipping industries (Larrazábal et al.,

2021). For example, Korean shipping companies integrate BT into their operations to generate sustainable profits (Bae, 2021).

Blockchain is able to follow activities such as vendor selection and supplier development, materials management and inbound logistics, production and internal operations, outbound logistics and marketing, and reverse logistics to create sustainable and green supply chains (Dutta et al., 2020).

2.1.4.4 Project management

Blockchain provides a powerful platform for many businesses to optimize their project management (PM), which helps them not only eliminate cost overruns and delays, but also improve process efficiency (Piney, 2012). Project teams and stakeholders can connect without any restrictions on a decentralized platform and follow all project affairs transparently. This means integrating PMs and stakeholders across all aspects of the project to track project progress and manage resources and coordinate tasks to avoid budget overruns and delays (Risius & Spohrer, 2017).

Blockchain is changing the way project stakeholders communicate. They are aware of the mediations that are done in the project by using smart contracts that facilitate the monitoring of each stage of the project's performance. They are actively involved with every stage of development and ensure that benchmarks are met. By implementing blockchain, buyers may be able to make payments without the need for intermediaries such as banks. This makes these financial transactions cost-effective and faster. People who do not even have access to traditional banks can pay through digital currencies such as Bitcoin (Hewavitharana et al., 2019). Another application of BC can be sharing lessons learned from projects with all team members, which avoids similar mistakes in organizations and implements best practices. In this regard, BC can be a valuable source for documenting lesson learned from each step of a project (Khatib et al., 2021). The advantage of BC is that it distributes competitive advantages to all stakeholders and improves he cost, time and quality of projects.

"The blockchain technology is extremely beneficial in PMIS in terms of simplifying the issues related to – intermediation and arbitration. This is because the technology offers the ability to project managers to define their concerns along with providing the explanation for the same to the stakeholders. This will also help in increasing the satisfaction of the customers." (Alkatheeri et al., 2023)

Blockchain is able to increase resiliency, sustainability and agility in PM area (Ivanov, 2020). Resiliency and flexibility in facing costs improves by performing short-term activities and increasing transparency in transactions. Through facilitating exchange between buyers and suppliers, agility of the project increases (Kamble et al., 2021). In a compact situation, BC can help decrease

the sharpness of costs, alleviate the risks involved in projects, increase quality, prevent wasting energy and protect the environment (cf. Figure 1).

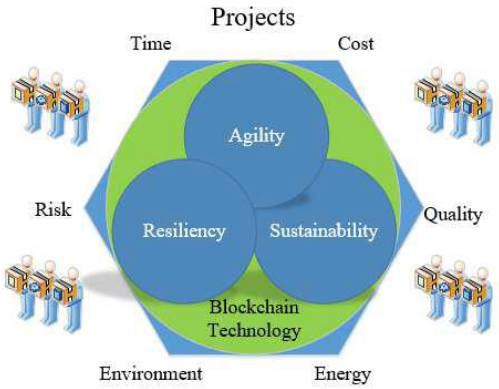


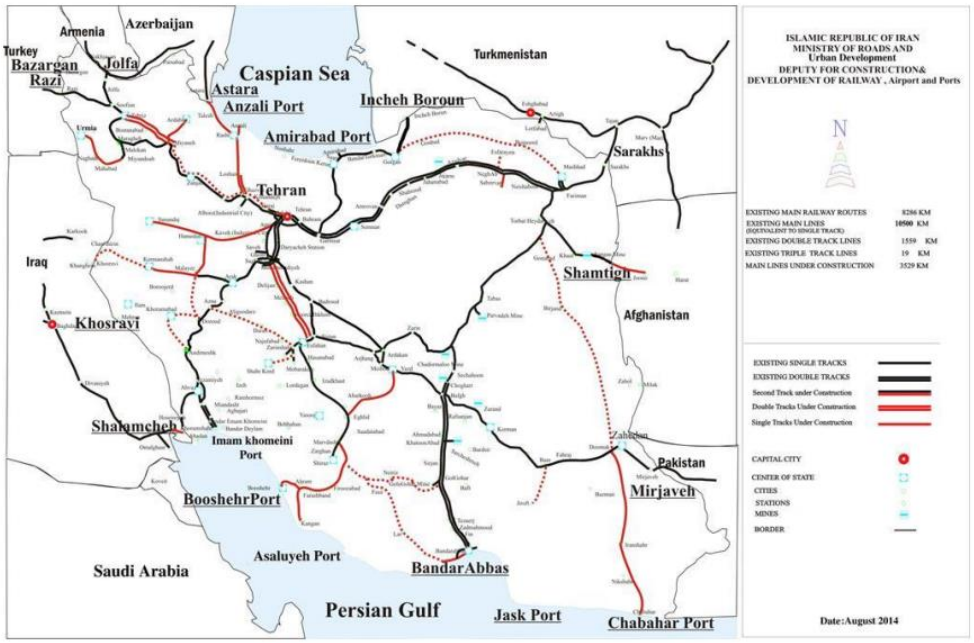
FIGURE 2. BLOCKCHAIN AND PROJECT CRITERIA (LOTFI ET AL., 2021)

Logistics is one of the most prominent and cost-oriented elements of SC, which includes all stages from production point to the consumption point. Hence, through blockchain technology, unnecessary losses and other irrelevant processes in logistics can be minimized to increase profits. In addition, inventory and reserves are one of the main pillars of any manufacturing concern, so accurate forecasting of required inventory as per demand is essential. In addition, timely inventory performance can minimize unnecessary ordering and inventory (Benton et al., 2018)

2.2 Supply chain challenges in railway industry (transportation)

2.2.1 Challenges faced in Iran

Iran has plans to expand its railway lines through 400 km and one of them is the lines which connect Persian Gulf Ports with its Caspian Sea Ports. It is an important project because it not only play an important role as an international multi-modal freight between South Asia, the Middle East, and Central Asia, but also it connects West to Europe and North to Russia (Silk Road Briefing, 2023).



Source: Iran railroads company

FIGURE 3. IRAN'S RAILROADS (SHAHRAKI, 2019)

Iran devote approximately $25 billion for new railway line projects over the next 10 years, but due to the current international problems and sanctions lots of companies are stoping working with Iran. For example the German company Siemens and the Swiss firm Stadler Rail have declared that they can not build and deliver products such as subway cars to Iran.

To use its potentials, Iran should solve some problems that affect railway industry including those faced the supply chain of this industry. These challenges in Iran are multifaceted and deeply intertwined with both international and domestic factors. On the one hand, the nation's ambitious investments, exemplified by the allocation of approximately $25 billion for new railway projects over the next decade, face setbacks due to international problems and sanctions, resulting in disruptions in collaborations with key foreign companies such as Siemens and Stadler Rail (Jalilov, 2018). On the other hand, inherent software-related issues further compound the challenges. These issues include bureaucratic paperwork, outdated standards, and fragmented management structures within the Iran Railway Company. Moreover, a glaring absence of reliable and coherent information across various transport sectors hinders progress toward a more efficient and productive railway supply chain (Shahjoi, 2022).

In terms of technology development in the transportation sector in Iran there are some issues including lack of proper infrastructures and expensiveness of adoption of new technologies, sanctions, lack of legislations and government intervention, data security concerns and lack of technical experts (shamizanjani, 2020).

According to studies, the most important challenges of rail transport are related to infrastructure, productivity, financing, logistics, legislation and supervision, management and bureaucracy, and low participation of the private sector. Among these challenges, infrastructure challenge with 24%, financing challenge with 15% and legislation, supervision, management and bureaucracy challenges with 12% each have the highest proportion of studies. In a way, it can be said that most of these challenges are related in some way to financing, and railway officials have paid attention to the bureaucratic challenge in solving it (Tin.ir, 2020). One of the new challenges in rail industry supply chain productivity is choosing the best suppliers of parts, equipment and raw materials needed by manufacturers and rail transportation service providers. This issue has become more severe in recent years with the tightening of sanctions on the rail industry (Javadi & Ahadi, 2021).

There are some factors that influence the development of logistics and supply chain in general in Iran which are inadequate transportation infrastructure, limited telecommunication infrastructure, worn out means of transportation, incomplete road network, insufficient warehouses, small and depreciated railway network, economic challenges, not paying attention to the advantage of competitive economy, small domestic market and lack of information in the market, inefficient banking system and high interest rates, inefficiency of the tax system and management challenges (Sadra Rajab Nejad, 2022).

There are many regulatory challenges in terms of applying blockchain in the supply chain of the railway industry. For example, the application of smart contracts requires binding and specific laws for legal support, and without defined laws and regulations, it is not possible to implement this technology in a real industrial environment. Another issue is related to financial and cyber crimes, which are not supported by preventive laws. Also, there are no specific rules and regulations regarding insurance and taxes related to transactions made on the blockchain platform.

In the field of technical and technological challenges, there are also obstacles such as solving the privacy concerns of companies and organizations, preventing manipulation and theft of information, the lack of a suitable infrastructure for information technology and also the lack of a suitable infrastructure for the IoT and finally time consuming process of transactions when the blockchain is expanded on entire supply chain network.

According to the announcement of the Central Bank of Iran in 2018, digital currencies such as Bitcoin are not approved and any transaction based on it is prohibited. According to CBI, these digital currencies are problematic because it is not clear who is behind these currencies and supporting them (Shirani & Talakesh, 2021). In many cases like this, government managers and legislators have deprived the country of the important benefits of blockchain technology in Iran due to their lack of proper understanding of the benefits and capabilities of this technology, with negative and restrictive attitudes (Wallex.ir, 2023).

2.2.2 Blockchain, transportation & logistics

There are some global challenges in logistics management in transportation. Apart from the selection of transportation type, the process of placing orders and managing them can be very complicated. The challenges also include carefully planning shipping schedules, tracking orders, and ensuring timely delivery of products to customers. As the complexity and scale of operations in the transportation sector increase, ensuring quality control becomes increasingly critical. For example, in certain areas such as packaging, strict quality control is critical, as shipped products must arrive at their destination without errors. To manage efficiency and optimize the supply chain, it is necessary to use appropriate management systems. However, these systems may be associated with challenges such as accurate measurement of logistics processes, sudden changes in demand and supply, security and privacy issues, and software cost. In transportation, human resource is used as one of the most important and vital resources in carrying out logistics activities and transportation of products, services and goods. Therefore, the management of this resource is very critical and plays a very important role in the success or failure of shipping companies (Nikavazeh, 2023).

Despite various efforts to find and solve problems in different sectors in supply chain, due to the lack of integration and the lack of central data sources that can solve different problems, they cannot always be solved in the whole chain. A main issue is that domestic companies cannot participate in international logistics activities due to the limitation of communication network and information technology. There is not an unified regulation in the supply chain, which causes delays and other related problems. Lack of knowledge of services, facilities and different parties in the supply chain is also important because knowing this information helps managers to make real-time and effective decisions and can also prevent future problems. (Rosena et al., 2008).

The movement of goods and people is greatly facilitated by the transportation and logistics sector, which is frequently referred to as the foundation of urban life. Security problems have, however, surfaced in the field of Intelligent Transportation Systems (ITS) due to the integration of cutting-edge technologies including big data analysis, artificial intelligence, and information technology (Guo & Guo, 2023).

Blockchain technology has become a game-changing response to the problems that China's Urban Intelligent Transportation Systems (UITS) are facing (Guo & Guo, 2023). As data authenticity and trustworthiness improve, blockchain technology has the ability to fundamentally alter the transportation and logistics sector. Using smart contracts to guarantee the accuracy of tracking data and project completion time estimations, it accomplishes this while lowering the risk of fraud (Ashraf & Ali, 2022). Moreover, blockchain technology has the capacity to establish governance norms and rules for the transportation, logistics, and supply chain sectors. This govern-

ance perspective sets the boundaries for blockchain-managed supply chains and practices, emphasizing transparency, traceability, and open information sharing as crucial principles (Pournader et al., 2019).

Furthermore, blockchain technology has the potential to provide governance standards and guidelines for the supply chain, logistics, and transportation industries. The boundaries for blockchain-managed supply chains and practices are established from a government perspective, which emphasizes openness, traceability, and open information sharing as core values (Pournader et al., 2019). The potential benefits of blockchain technology also extend to the marine and shipping supply chains, where it can improve transparency, lower transaction costs, and streamline operations. Blockchain can be used to automate procedures, manage shipments, detect infractions, and boost supply chain effectiveness when combined with IoT-enabled smart containers. Blockchain technology have already been deployed by businesses like Maersk and Samsung to digitize and improve their container shipping operations (Dutta et al., 2020). Through distributed data storage, smart contracts, and enabling technologies like IoT devices and GPS, blockchain also provides a solution for making maritime and shipping supply chains traceable. By increasing transparency, automating transactions, and increasing overall efficiency, this technology has the potential to revolutionize these industries (Pournader et al., 2019).

2.3 Barriers and challenges in adopting blockchain in supply chain

Due to the failure of some blockchain projects in their infancies, there are now concerns about the practical application of this technology in the transportation sector (Astarita et al., 2019) and although there are many examples of successful SC development with blockchain, there are still hurdles in terms of security, privacy, cost and usability (Dutta et al., 2020).

As an advanced technology, it is not yet fully understood by industry players. This lack of understanding is a barrier to adoption and is as important as its technical implications (Preece, 2020). Currently, there are many problems in the practical application of blockchain technology (Khan & Salah, 2017; Li et al., 2020). For example, many governments have called digital currencies illegal (Morwani & Mandalia, 2020), the distributed storage structure requires hardware infrastructure for the actual physical node, the transaction processing rate is low, the consensus mechanism is still vulnerable, the throughput of the blockchain system is limited, and the smart contract may be attacked. These problems still limit the application scope of blockchain technology in practice, and the key to solving these problems is to create a good blockchain development environment in all fields (Ghaemi et al., 2021).

Cost of deploying new technologies is another obstacle to the adoption of BC in the supply chain and logostics. This cost is related to the cost of capital and installation of information technology,

while organizations are conservative in their capital expenditures (Ghobakhloo et al., 2012). According to Saberi et al. (2019), data manipulation in the supply chain network is problematic because each participant is given the ability to verify transactions. They add that privacy data security are other factors that should be considered before implementing BC in the supply chain.

3 METHODOLOGY

In this section, the method I used to conduct this research is explained. This is a qualitative research based on in-depth expert interviews. Before conducting the interviews, I did a literature review to provide insight into conducting in-depth interviews and to determine what the objectives of the research were and what the interview questions would be. Since the amount of secondary data available in this field is limited due to the newness of this issue in the Iranian railway industry, it is expected that the majority of the results would be obtained from the primary data achieved from the interviews. This can be realized in the literature review section, which is a bit shorter than it should be.

As the next step, the interview guideline was written. The interview guideline is along with the findings that are collected through literature review discussed in section 2 and aims to bridge the identified gap between existing findings and the opinions extracted from the interviews. All the interviewees got informed about anonymity and confidentiality of the research and has given their consent to be interviewed and for their answers to be used and analyzed in this research. For each interview, I gave the information transcripted to every interviewee in order to check the accuracy of the data. The data collected were treated in compliance with ethical guidelines.

The following sections goes through this methodology for conducting qualitative research in detail to investigate the perspectives and insights of managers, experts, and activists within the Iranian railway industry. This research utilizes in-depth interviews, transcription, translation, coding, and thematic analysis to derive meaningful insights.

3.1 Participants and Sampling

According to Clarke and Jack (1998) qualitative research is defined as a way of describing events inside a context which are used to explore complex or new areas. In my research, the context is supply chain of railway industry and the subjects are the activists in this field. The current study involves 15 participants who were selected based on their extensive experience and expertise in the railway industry in Iran. Therefore, the sampling technique was employed was purposive sampling to ensure that the knowledge of the interviewees are in line with the purpose of this study. The participant pool was drawn from diverse backgrounds, encompassing managers, experts, and other activists who are mainly working on railway construction projects in Iran.

The sampling process for my research was one of the most time-consuming and energy-taking parts, as there are not many activists who are familiar with the concept of blockchain. The good thing was that most of the interviewees were my colleagues in the railway projects and they also helped me in finding other participants. Participants who all worked in the railway industry but are now scattered around the world. Two of them live in America, one in Australia, one in

New Zealand, one in Germany and the other in Austria. The rest are now living in Iran and are still active in the railway sector. It was really difficult to coordinate with all these people, especially those who now live in other countries, mainly due to time differences and scheduling issues. The process of finding these participants started on March 10 and continued until May 7.

3.2 In-Depth Interviews

According to the Longhurst (Longhurst, 2009), interviews are often defined as verbal basis interactions between two parties. The first party is the interviewer who asks questions and the second party is interviewee who answers these questions. I chose in-depth interviews as the primary data collection method. These interviews allowed for a deep exploration of participants' perspectives and experiences. The interviews were semi-structured, ensuring flexibility through 12 open-ended questions (See Appendix 1) while addressing core research questions. Using a semi-structured interview, according to what Adhabi (2017) defines, allows the interviewer to keep an open mind of what can emerge (Bryman, 2016). Semi-structured interviews are situationally similar to structured interviews, that is, a predefined framework of questions is set. Nevertheless, the interview framework is flexible because the interviewer can allow the interviewee to be guided by the development of the interview and is not strictly committed to the current framework (Creswell, 2014). The interviews were conducted both in English and Farsi to accommodate participants' language preferences. An interview guide composed of semi-structured, open-ended questions was approved by Modul University Vienna's Institutional Review Board (IRB).

According to the type of interview setting, there are four categories including face-to-face interview, telephone interview (current online interview), focus group interview and finally email interview (Creswell, 2014). The latter is not recommended because it does not allow constructive interaction between the first and second parties. Of my 15 interviews, 7 were face-to-face interviews, 6 were online via Microsoft teams, and 2 refused to do direct interactive interviews. In order to have enough time to reflect and recover knowledge by participants, the interview questions were sent a day before the interview date. I also created and sent a short introduction in the form of a PowerPoint file to a number of interviewees who were not familiar with all aspects of BC.

3.3 Data Recording and Transcription

I chose in-depth interviews for data collection because in-depth interviews are described as the most common and valid method in qualitative research (Ritchie & Lewis, 2003). In the trip that I planned only for face-to-face interviews, 7 participants were interviewed in Iran. These interviews are all audio recorded. 6 Participants (especially those now in other countries) were interviewed and recorded online via Microsoft Teams. 2 of the interviewees preferred to have an indirect interview and sent the answers by email. All recorded interviews were transcribed word

by word. Transcripts were cross-checked for accuracy d completeness. In cases where interviews were conducted in Farsi, transcripts were prepared in Farsi before translation into English to ensure linguistic accuracy. Due to the lack of English proficiency of some of the interviewees, I changed some phrases in a way that the whole meaning of the answers remained unchanged.

3.4 Data analysis

For the purpose of the results analysis thematic analysis was conducted using guidelines of Braun and Clarke (2006). This guideline includes the steps below:

• Initial coding

• Grouping of initial codes

• Review of code groups and identification of themes

• Review of themes and association of transcript quotations with codes

• Rearranging themes and write up

The data analysis process began with initial coding and all the steps abow were taken carefully. Transcripts were entered into software designed for qualitative data analysis and thematization called QDA Miner. I used a special version of this software called QDA Miner Lite. After entering all the interview texts in this software, I managed to find the themes and categorize them with the facilities provided by this software. An initial set of codes was developed and these codes were applied to identify recurring patterns, concepts, and ideas in the data across sections of the text. Then the themes obtained from different categories of responses are understood and analyzed in depth. For easier understanding of the results, the themes and codes derived from the texts were depicted by the diagrams and charts provided by the software.

4 RESULTS

4.1 Presentation of the findings

4.1.1 Extracted Codes

4.1.1.1 Problems and Challenges

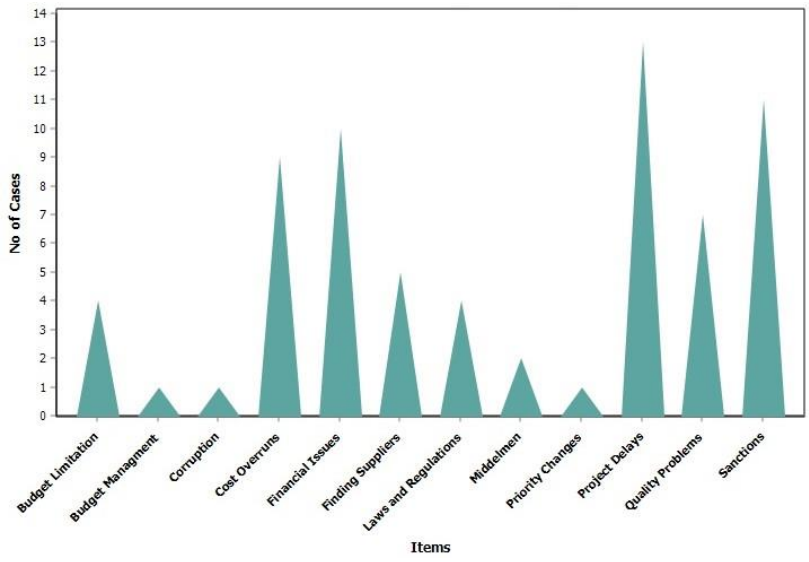


FIGURE 4. PROBLEMS AND CHALLENGES

As the chart shows, railway projects in Iran are facing a wide range of problems and challenges, of which project delays are the most important. According to the interviewee's statements, these delays are caused by problems other than bad planning, and only a small part of these delays are caused by mismanagement and incorrect timing. The main reason of these delays is mainly caused by other challenges such as financial issues, sanctions, budget restrictions, which themselves are also mentioned as the most important challenges. Financial issues in themselves are one of the main challenges, with problems in money transfers, late payments by major clients, which are mostly government-owned enterprises, and budget limitations separately cited as problems. Sanctions imposed on Iranian industry are the second main problem. These sanctions create many other problems, the most important of which is cooperation with reliable and high-quality international suppliers who are not willing to cooperate with Iranian companies due to the threat of sanctions. Another consequence of sanctions is the limitation or impossibility of money transfer, which reduces the number of international suppliers who intend to cooperate with Iranian companies. As a result, it becomes more difficult to find quality vendors, and sometimes contractors are forced to replace them with internal vendors, which lowers the quality of projects. Rules and regulations have been put in place to facilitate the processes, but sometimes there are rules and regulations that hinder the process of supply of goods. For example, customs clearance rules and regulations are constantly changing and as a result extending the period of

delivery. Another law prohibits the use of new technologies and solutions such as digital currencies and smart contracts in Iran. There are also laws that require companies to support domestic production, which results in a decrease in quality due to the formation of monopoly and even affects the cost of projects. All these factors affect the cost of projects and lead to a cost-overrun which is one of the main problems of railway projects. Project delays, cost overruns and quality reduction are among the most important challenges of projects, which shows that the three main pillars of projects in Iran are affected by various challenges and problems.

4.1.1.2 Blockchain solutions

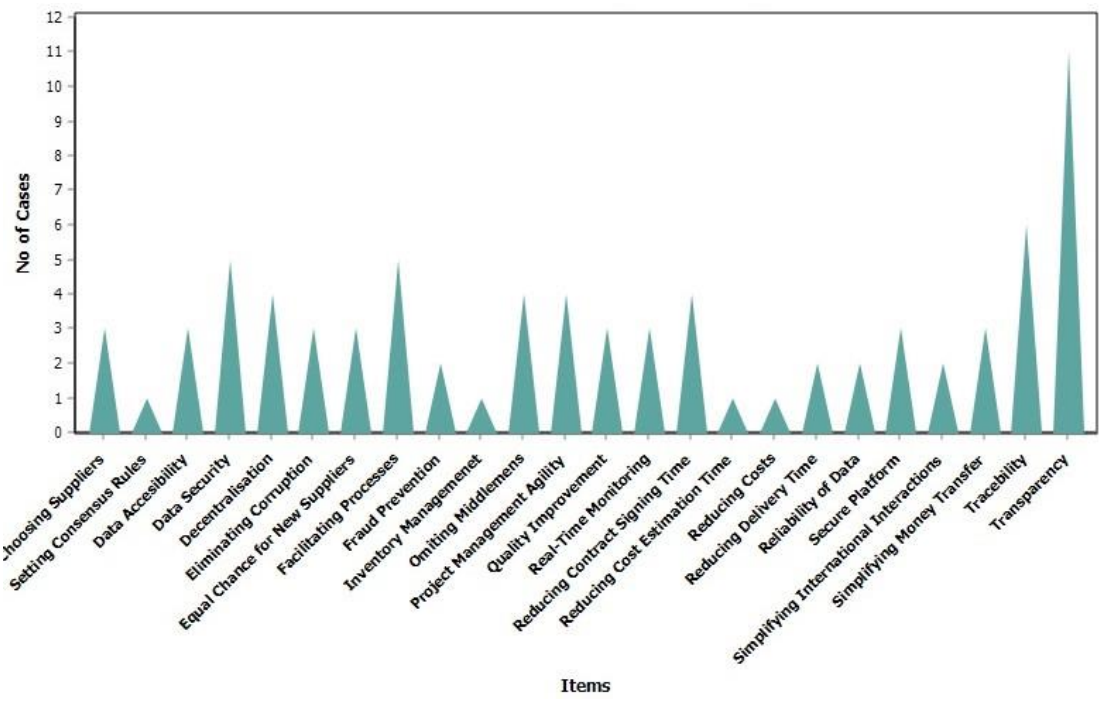


FIGURE 5. BC SOLUTIONS

As the chart shows, it's no surprise that blockchain brings many benefits to the supply chain and has many different uses. If implemented in the future, it will be a great solution for Iran's railway industry. Among the features named, transparency is by far the most prominent feature. Because the systems in Iran in general and supply chains in the railway industry in particular suffer from a lack of clarity, and blockchain can provide a platform where information is transparently available to all users and they can benefit from this. The users of blockchain can reliably do business and take the advantage of a blockchain-based cpmpetitive market. After increasing transparency and in the second layer, three solutions could be seen, which are traceability, process facilitation and data security. Through the information recorded in the blockchain, buyers can easily access the origin of the products and make sure that what they are buying is of high quality. Transactions are facilitated by blockchain because there is a common platform and smart

contracts shorten many processes. Data stored in the ledger is approved by all the users and is immutable, so data security is guaranteed.

Agility of project management, reduction of time, decentralization and elimination of intermediaries are the features that are in the third layer of importance. A common platform that everyone involved in the project can see and work with can transform the traditional method of project management into an agile one. Agile PM combined with smart contract tool reduces project time. It also avoids the control of a single entity and distributes the governance of processes throughout the entire chain, which has very positive consequences and avoids a single point of authority and its negative consequences such as corruption. The role of middlemen can be reduced by implementing blockchain because transactions can be done directly and payments can be made through digital currencies, which in turn is one of the most useful features of blockchain.

As the fourth layer, finding and selecting suppliers becomes easier due to transparency, data access increases as all users from anywhere in the chain are able to access data, new suppliers are given equal chance of competition, the buyers have the possibility of real-time monitoring of their orders, money transfer is simplified and a secure platform for transactions is achieved.

4.1.1.3 Barriers to implementation

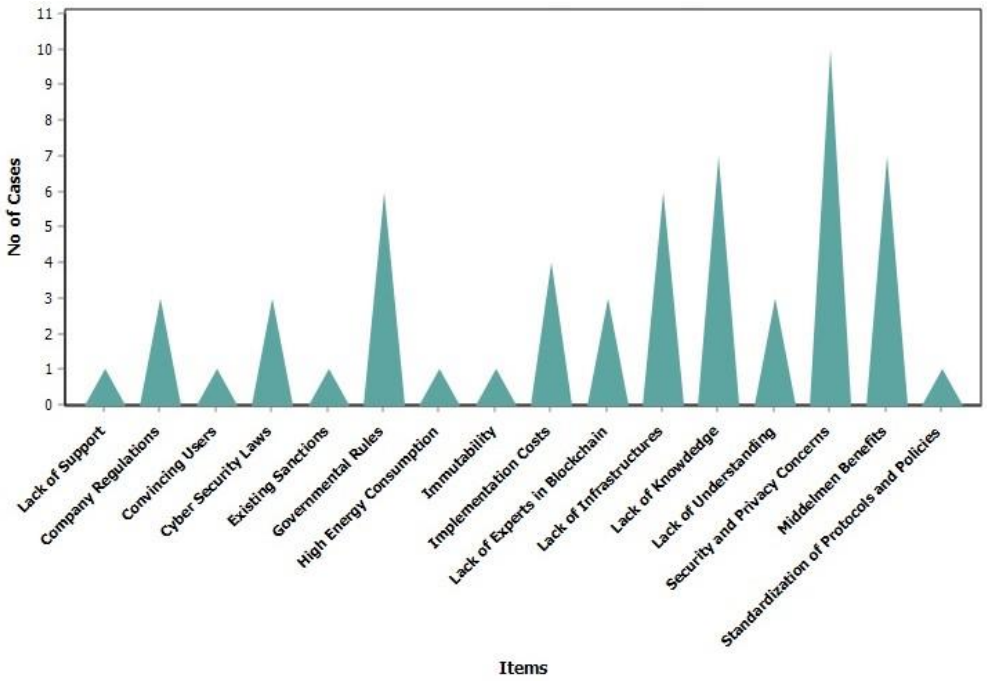


FIGURE 6. BARRIERS OF IMPLEMENTATION

As with any new technology, there are hurdles and difficulties in terms of implementing blockchain technology in the supply chain of the rail industry. The biggest deterrent is security and privacy concerns. Although the data stored on the chain is secure and cannot be easily manipulated, there are some data that companies are reluctant to share because the data may be misused. For example, some companies have competitive advantages such as sourcing and designing their own products, and in a common platform, this data can be sold to competitors or copied by other companies.

After security and privacy concerns, lack of knowledge, lack of infrastructures, intermediaries, and government regulations are the most important barriers to implementing blockchain technology. Lack of awareness can be examined from two perspectives. One is the lack of technical understanding and the number of experts who are familiar with the concept and are able to develop this new technology. Another case is that managers are not familiar with the consequences and benefits that BC can bring to their management area. Beside the lack of knowledge, the industry in Iran in general and railway industry specifically, suffer from inappropriate infrastructure that could be looked at from technical perspective as well as regulatory issues. Intermediaries, also known as third parties, are the ones who lose their profits, as blockchain enables direct transactions between buyers and sellers, as well as direct payments, without the need for intermediaries such as banks. Sometimes, due to the corruption that exists in various sectors of the industry in Iran, especially in the government sector, these companies support these intermediaries by establishing laws and regulations. Government laws are also restrictive in other ways. For example, free trade is prohibited with some countries hostile to Iran because the use of their products in sensitive industries such as public transportation could pose a potential threat. There is also a rule to protect domestic products, which prevents companies that want to take advantage of the free competition market. Implementation costs are another important obstacle to the implementation of blockchain technology.

4.1.1.4 Convincing Stakeholders

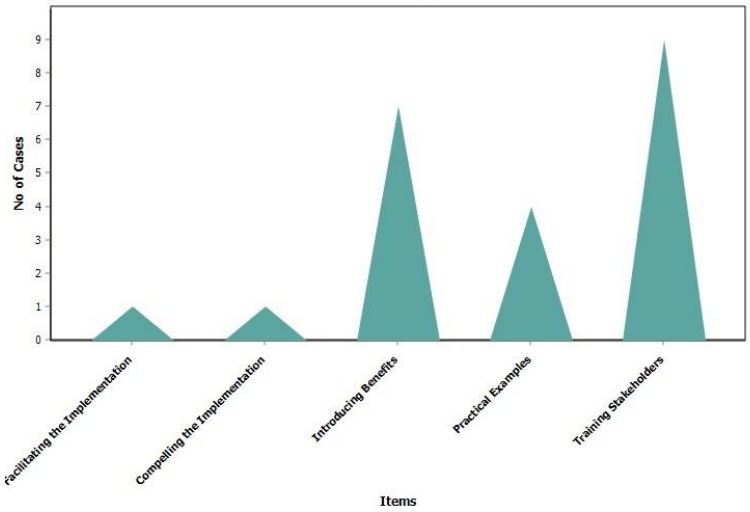


FIGURE 7. CODES FOR CONVINCING THE STAKEHOLDERS

In the end, it is the stakeholders who decide whether or not to use new technologies in their business. As explained in the previous section, there are many barriers to implementation for which solutions were recommended by the interviewees. These solutions, in order of importance, include the education of the beneficiaries, the introduction of benefits, Providing practical examples, facilitating implementation and finally forcing stakeholders to use this new technology. The main factor that motivates stakeholders to use BC is education. Only by training they will get to know the whole concept and understand the advantages and disadvantages of using this technology. After training, they can evaluate the feasibility of blockchain implementation and know how it can be built in the organization and implemented by users. Introducing the benefits of BC is also part of the training and helps a lot in convincing stakeholders to implement this platform. Without making sure that the advantages of blockchain technology outweigh its disadvantages, it is not possible to build the infrastructure and create this system. To show its benefits, successful projects that have become more efficient using blockchain can be introduced. In Iran, there are startups that use it in some pilot projects, but there are also international businesses that are successful examples of blockchain implementation, such as Amazon. Of course, the infrastructure can be created to convince the stakeholders, but in Iran, due to the lack of sufficient investment in such a field, and on the other hand, the fact that most of the actors are governmental, it is understandable that a complete introduction and proof of profitability is needed before any action. In Iran, the public sector as well as large players such as Mapna Group can force their partners to use a common platform and it can be another solution to start using it and after seeing its success, implementing it in whole business.

4.1.2 Clustering the Codes

After thematizing all codes, 4 main-clusters are extracted which are compatible with research questions and for each main cluster, there are some sub-clusters which are shown in in the tables below. Based on the frequency af the cases who answered the questions, the pie charts show the weight of opinions for each main-cluster

4.1.2.1 Problems/Challenges within the supply chain

Cluster 1: Budgetory Challenges	Cluster 2: Compliance Challenges	Cluster 3: Suppliers	Cluster 4: Project Hurdles	Cluster 5: Intermediaries
• Budget Limitation • Budget Management • Financial Issues	• Corruption • Laws and Regulations • Sanctions	• Finding New Suppliers	• Priority Changes • Project Delays • Quality Problems • Cost Overruns	• Middelmen

TABLE 1. SUB-CLUSTERS FOR PROBLEMS AND CHALLENGES

5 clusters were formed based on the responses answering the first research question: What specific issues/challenges within the Iranian railway industry supply chain hinder operational efficiency and hinder effective resource utilization?

I grouped the responses I received from participants into five clusters, including budget challenges, compliance challenges, suppliers, project hurdles, and intermediaries. Budgetary challenges (Cluster 1) arise for three main reasons, listed as sub-clusters in the table. Budget limitation means lack of enough investment by the government, budget management refers to problems caused by lack of proper allocation of budgets and lack of proper schedule for budget spending, and financial problems describe problems caused by sanctions and difficulties in making payments through conventional payment channels. Compliance challenges (cluster 2) originates from three main causes: corruption, laws and regulations, and sanctions. Laws and regulations sometimes hinder rather than facilitate and have the same results as international sanctions and restrict some activities such as finding the best suppliers. There is also corruption, which is encouraged by setting inadequate rules. The third cluster is about suppliers. As described, some laws and regulations as well as sanctions make it difficult to find high-quality suppliers. Additionally, new suppliers do not have the opportunity to compete fairly in traditional systems and need a platform that gives them the opportunity to be approved and included in vendor lists without imposing risk on buyers.

There are also issues affecting project management processes seen in Cluster 4. All three pillars of projects, namely time, cost and quality, are in a bad situation in current projects. The details of how these parts affect each other and influence the success of the projects are explained in Section 4.2.1.1. There is also the problem of priority changes, which arise from changing the priority of supplying a system while one part of it is done, and there is a need to jump to the other system that is needed sooner due to the priority change. This problem leads to time extensions and cost overruns. Cluster 5 is about intermediaries that have some negative consequences, as mentioned in Section 4.2.1.1, although they are intended to facilitate certain activities in current situations, such as money transfers or acting as intermediaries to enforce sanctions evade. The pie chart below- Figure 8- shows how large these five clusters of challenges and issues are compared to each other.

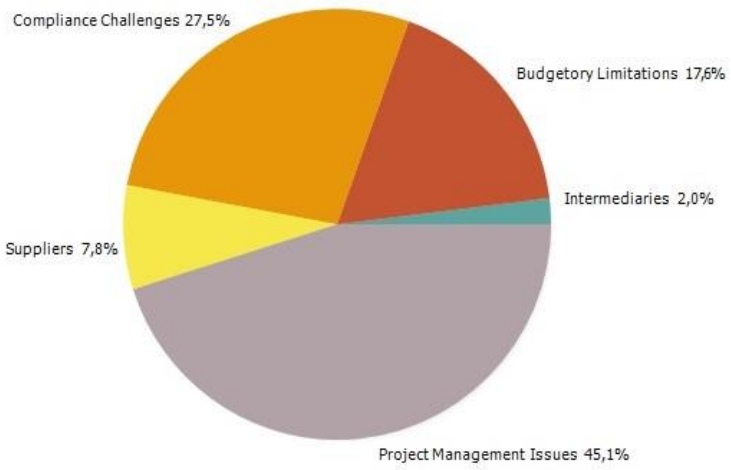


FIGURE 8. PROBLEMS AND CHALLENGES

4.1.2.2 Blockchain solutions

Cluster 1: Interactions	Cluster 2: Data Integrity & Transparency	Cluster 3: Preventing Misconduct	Cluster 4: Project Management
• Choosing Suppliers • Simplifying International Interactions • Simplifying Money Transfer • Setting consensus rules	• Data Accessibility • Data Security • Decentralized System • Reliability of Data • Secure Platform • Traceability • Transparency • Real-Time Monitoring	• Avoiding Corruption • Equal Chance for New Suppliers • Fraud Prevention • Omiting Middlemen	• Facilitating Processes • Inventory Managemenet • Project Management Agility • Quality Improvement • Reducing Costs • Reducing Contract Signing Time • Reducing Cost Estimation Time • Reducing Delivery Time

TABLE 2. SUB-CLUSTER FOR BC SOLUTIONS

Table 2 is based on 4 realized clusters that answer research question 2: What are the applications/benefits of blockchain technology in solving these problems and increasing the efficiency of the supply chain?

The first solution, categorized as Cluster 1, is facilitating interactions. Since blockchain provides a reliable platform, parties can easily trust each other and rely on the system to conduct business. Only suppliers that are recognized by every nodes can be part of the chain, making the process of supplier selection easier and faster. Smart contracts are shortcuts for contracts that require long-term negotiations and trust-based relationships, especially at the international level. In addition, transferring funds in a sanctions situation is very difficult and requires intermediaries, but cryptocurrencies can be a good solution for this. Since blockchain is an advanced platform for many parties to transact with each other, setting consensus rules is necessary, and setting these rules provides a faster and more reliable tool that offers a solution to every possible problem. Cluster 2 is about data integrity and transparency. This is the most commonly cited feature of blockchain, as Iran suffers from ambiguity in many processes and reliable data is rarely available. The fact that data is not controlled by a special authority and must be verified by all nodes (decentralization) makes it secure and transparent. Each node should access the same data as other nodes. In addition, every transaction should be stored on the chain so that all

transactions can be traced. In addition, the transparency and the ability to link to other technologies such as IoT make real-time monitoring possible.

Especially in countries like Iran, which suffer from ambiguity, preventing misconduct (cluster 3) is very difficult. Blockchain enables this prevention by providing equal opportunities to new suppliers and creating a competitive environment, preventing fraud, eliminating middlemen and avoiding corruption. There are already some companies that have a monopoly in Iran, and other companies are unable to compete in a fair market due to the advantages offered to them. With Blockchain, new suppliers have the chance to become a recognized provider where companies can easily rely on the quality of their products and prices. Eliminating middlemen could also reduce corruption. The traceability feature that BC provides means companies cannot sell counterfeit products or substandard products made from inferior raw materials and components.

Cluster 4 shows how BC can affect project management. Smart contracts and data accessibility are two main factors that accelerate the process of supplying goods. Everything regarding supplying goods for the projects are available in the ledgers, therefore inventory management becomes possible. When all the processes are defined and stored on the chain and available for all parties, those involved in project management can work simultaneously to solve a problem. For example, when there is a delay in custos clearance, they can see the problem in a rel-time and try to find the root of the problem and solve it. As a result of this, using smart contracts, and shortening the time of payments, the tie required for signing contracts ans as a consequence the delivery time decreases. Three main pillars of the projects are also affected significantly as discussed in section 4.2.1.2. The pie chart below- Figure9- illustrates in which areas and to what extent BC can be a solution for the problems that exist in the supply chain of railway industry in Iran.

Cluster 4 shows how BC can influence project management. Smart contracts and data availability are two main factors that speed up the process of delivering goods. Everything related to the delivery of goods for the projects is available in the ledgers, allowing inventory management. When all processes are defined and stored in the chain and available to everyone involved, those involved in project management can work on solving a problem at the same time the problems occur. For example, if there is a delay in customs clearance, they can identify the problem promptly and try to find and solve the cause of the problem. Through the use of smart contracts the reduction of payment time, the reduction of time required to sign contracts, the delivery time could be reduced. Three main pillars of the projects are also significantly affected, as explained in Section 4.2.1.2. The following pie chart - Figure 9 - illustrates in which areas and to what extent BC can be a solution to the problems that exist in the supply chain of the railway industry in Iran.

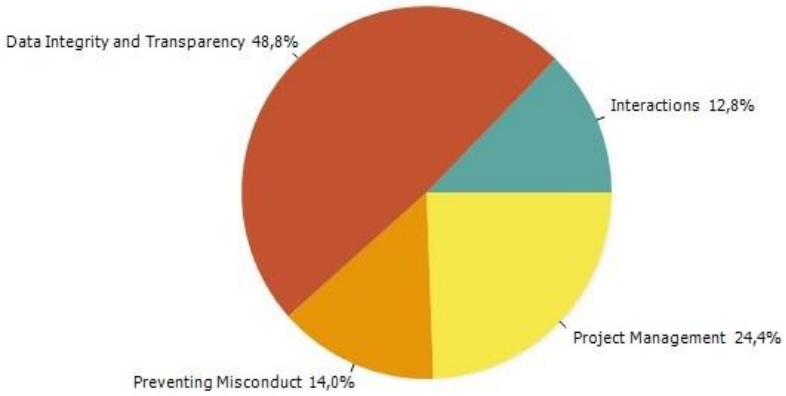


FIGURE 9. BC SOLUTIONS

4.1.2.3 Barriers to Adopting Blockchain

Question3: What are the main infrastructural, technical, and regulatory barriers that hinder the adoption of this technology in the context of the Iranian railway supply chain?

Cluster 1: **Infrastructural Barriers**	**Cluster 2:** **Technical Barriers**	**Cluster 3:** **Regulatory Barriers**
• Lack of Experts in Blockchain • Lack of Infrastructures • Lack of Knowdedge • Time to Understand Blockchain • Convincing Users	• Immutability of Data • High Energy Consumption • Implementation Costs • Blockchain not Supported	• Middlemen Benefit • Security and Privacy Concerns • Standardization of Protocols and Policies • Company Regulations • Cyber Security Laws • Existing Sanction • Governmental Rules

TABLE 3. BARRIERS OF IMPLEMENTATION

The barriers to blockchain technology adoption are listed in Table 3 and divided into three main clusters, including infrastructural barriers, technical barriers and regulatory barriers. Blockchain is one of the technologies that requires a variety of infrastructure and prerequisites. Due to the newness of this technology, the number of experts trained to develop the BC platform in the supply chain is small and only a few experts are working on some start-ups and pilot projects in Iran. When there is a lack of implementation, there is lack of awareness and knowledge among stakeholders, managers and technical experts in the field as a consequence. The process of proving the usefulness and profitability of blockchain is currently very lengthy due to a lack of knowledge and understanding among managers and decision-makers. Since blockchain should be built on a strong foundation and this foundation is currently very incomplete in Iran, it needs time to be applied in various industries and especially in the supply chain of the railway industry, considering that the railway industry is not a modern industry and This also has a tendency to resist the use of such technologies.

Cluster 2 talks about technical obstacles to implementing blockchain. Two of these technical obstacles are very problematic in Iran. The first one is that blockchain is not supported by other systems. BC requires defined protocols and software and hardware that support its expansion across the network, and this support does not yet exist. The second one is the implementation cost of the blockchain. Budget constraints do not allow funding for blockchain-based projects, and without sufficient funding, it is almost impossible to switch to blockchain technology in Iran. Only the private sector is able to scale it, which is not enough as the majority of projects defined in Iran belong to the state sector.

Regulatory obstacles are shown as cluster 3. There is hardly rules, regulations and instructions that encourage using blockchain. In contrary, there are prohibitive rules that hinders the expansion of this technology. As an example, using crypto currencies as a payment tool is prohibited in Iran and it is because of the fact that on the one hand, the government does not want to lose the control of the flow of the money and on the other hand, it wants to support banks and other financial entities who act as intermediaries. As another example, the law of protecting domestic products says that the buyers are not able to take the full advantage of using a BC based competitive market on which the suppliers are members of a big platform and can share valuable information in terms of supplying goods. Cyber security rules also prevent using it. For example, the policy does not allow sharing some sensitive information specially in railway industry that the passenger information as well as design information matter. Sanctions are another and one of the most important barriers of blockchains. The software and hardware that is required to develop this technology cannot be easily bought. In addition, companies themselves have some constraint regarding sharing their information because it may lead to losing their competitive advantage. Finally, there is a lack of standardization of protocols which is very problematic and needs lots of time and energy and a group of experts and jouristics to define these standards which facilitate the use of this technology.

Regulatory obstacles are presented as Cluster 3. There are hardly any rules, regulations and instructions that promote the use of blockchain. On the contrary, there are prohibition rules that hinder the spread of this technology. For example, the use of cryptocurrencies as a means of payment is prohibited in Iran because, on the one hand, the government does not want to lose control over the flow of money and, on the other hand, it wants to support banks and other financial institutions that act as intermediaries. As another example, the law of protecting domestic products says that the buyers are not able to take the full advantage of using a BC based competitive market on which the suppliers are members of a big platform and can share valuable information in terms of supplying goods. Cyber security rules also prevent its use. For example, the cyber security policiy does not allow the sharing of sensitive information, particularly in the railway industry, which involves both passenger information and design information. Sanctions are another and one of the most important obstacles of blockchains' expansion. The software and hardware required to develop this technology cannot be easily purchased. In addition, companies themselves are subject to certain restrictions on sharing their information, as this may lead to a loss of their competitive advantage. Finally, there is a lack of standardization of protocols, which is very problematic and requires a lot of time and energy as well as a group of experts and juristics to define those standards that facilitate the use of this technology. The following pie chart- Figure 10- shows the significance of the barriers in comparison to each other.

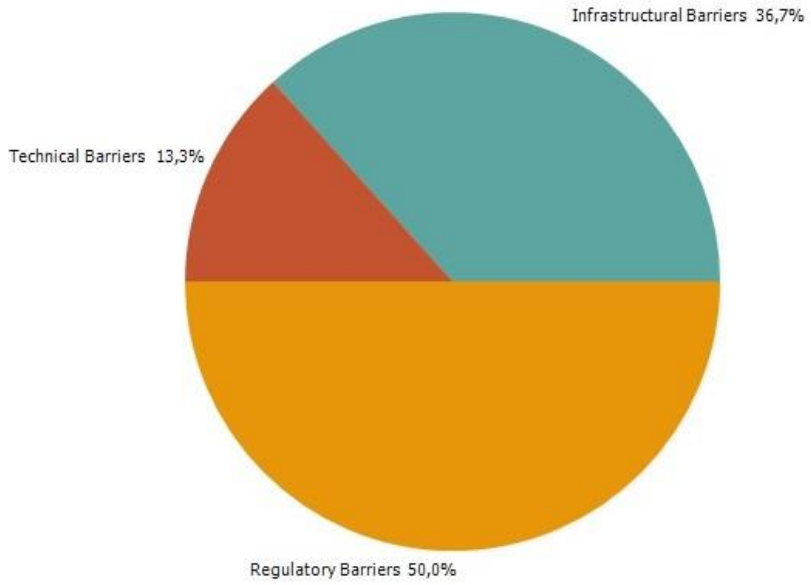


FIGURE 10. BARRIERS OF IMPLEMENTATION

4.1.2.4 Convincing the stakeholders.

Cluster 1: Providing Infrastructures	Cluster 2: Obligation	Cluster 3: Benefits
• Facilitating Its Applications • Training Stakeholders	• Compelling them to Employ the Platform	• Introducing Benefits • Providing Practical Examples

TABLE 4. SUB-CLUSTERS FOR CONVINCING STAKEHOLDERS

Table 4 shows the measures that can be taken to convince stakeholders to adopt blockchain in their business. One of these measures mentioned in Cluster 1 is facilitating its application. There should be a will behind the expansion of BC aimed at eliminating the problems and removing the obstacles. Such an approach and will does not currently exist and, as described in Section 4.2.2.1, prohibition rules contradict this. Another factor that is urgently needed for the provision of a cultural infrastructure is the training of those involved. Decision makers should be aware of all aspects of blockchain, from technical issues to the benefits of implementation.

Cluster 2 presents a solution that is necessary and should be part of the expansion process. Some companies that are pioneers in their industry should force their suppliers and other partners to provide the infrastructure for the use of blockchain, thereby forcing the use of blockchain with their pioneering efforts. For example, the Mapna Group company may set up a unit under the supervision of the R&D department aimed at conducting a pilot project on the use of BC in the supply chain of one or some of its projects. It can then introduce this new technology to other stakeholders and suppliers and compel them to participate in this project so that collaboration continues and all parties reap the benefits of BC implementation.

Cluster 3 aims to show that introducing the benefits of blockchain can motivate stakeholders to use blockchain. Of course, as with all other new technologies, there are some costs associated with developing and maintaining blockchain technology, but these stakeholders and decision makers must ensure that the benefits of this technology outweigh its disadvantages, particularly its costs. To do this, some successful projects can be used to present practical examples that lead to the projects and companies becoming more profitable. The following pie chart – Figure 11 – shows the effectiveness of using these persuasive factors compared to each other.

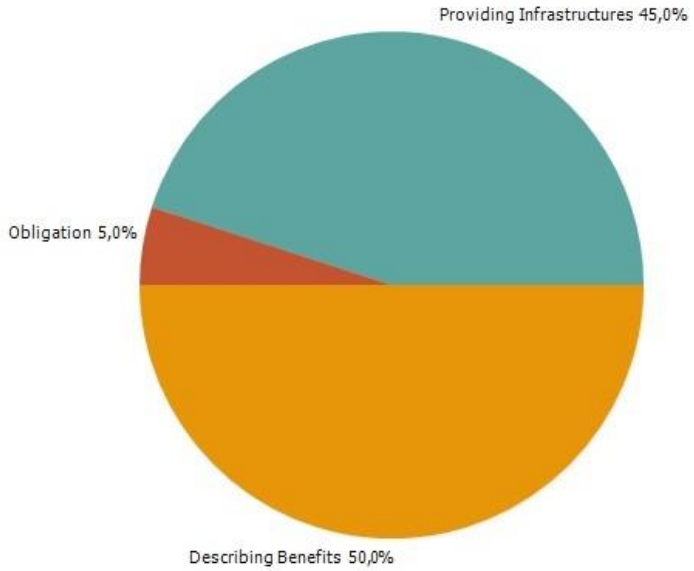


FIGURE 11. CONVINCING FACTORS

4.1.3 General Word Cloud

A general world cloud based on all the codes which are extracted

FIGURE 12. GENERAL WORD CLOUD

Finally, to visualize the frequency of all the terms derived from the answers, I used the above word cloud (Figure 12). This gives a whole picture to those who want to know which themes and concerns exist around the subject of blockchain application in supply chain in focused industry. The size of each code is proportional to its frequency within the whole text. With a quick look at this word cloud, it is easily noticeable that “Project Delays” are the most prominent concept regarding supply chain problems and application of blockchain in it in railway industry in Iran. Project delays is the biggest challenge faced by supply chain . “Sanctions” are ranked as second concerning issue and is another challenge and cause of many problems in this field. After sanctions the terms “Cost Overruns”, “Security and Privacy Concerns”, “Financial Issues”, and “Transparency” are shown with the same degree of importance. Cost overruns is another problem which is resulted from different reasons such as project delays, financial issues, mismanagement, sanctions etc. security and privacy concerns fall in the category of barriers to implementation of blockchain. Financial issues also are also among the most prominent challenges, and transparency is a solution that blockchain technology offers to the industry, although it could be a problem at the same time. “Quality Problems”, “Lack of Knowledge”, “Finding Suppliers”, “Introducing Benefits”, and “Traceability” can be sorted together as the next important category of terms. Quality problems originate from sanctions, finding new suppliers, laws and regulations and monopoly, lack of knowledge is one of the barriers of implementation of BC, finding suppliers is a challenge that is resulted from sanctions and some domestic rules like protecting domestic products, introducing benefits is a way of convincing the stakeholders to apply BC, and finally traceability is one of the most important applications of this technology.

Finally, to visualize the frequency of all terms derived from the answers, I used the word cloud above (Figure 12). Anyone who would like to know what topics and concerns there are around the topic of blockchain application in the supply chain in the focused industry will receive a comprehensive picture. The size of each code is proportional to its frequency throughout the text. A quick look at this word cloud reveals that “Project Delays” is the most well-known concept related to supply chain issues and the application of blockchain in the railway industry in Iran. Project delays are the biggest challenge for the supply chain and a big concern for managers. “Sanctions” come second and are another challenge and cause of many problems in this area. After sanctions, the terms “Cost Overruns,” “Security and Privacy Concerns,” “Financial Issues,” and “Transparency” gain the most importance. Cost overruns are another problem that arises due to various reasons such as project delays, financial problems, mismanagement, sanctions, etc. Security and privacy concerns fall into the category of barriers to blockchain implementation. Financial issues are also among the biggest challenges, and transparency is a solution that blockchain technology offers the industry, although it could itself cause many problems. “Quality Problems”, “Lack of Knowledge”, “Finding Suppliers”, “Introducing Benefits” and “Traceability” can be summarized as the next important conceptual category. Quality problems arise from sanctions, finding new suppliers issue, laws and regulations and monopolies, lack of knowledge is one of the obstacles in the implementation of BC, finding suppliers is a challenge arising from

sanctions and some domestic rules such as protection of domestic products, introducing benefits is one way to convince stakeholders to adopt BC, and finally, traceability is one of the most important applications of this technology.

4.2 Extracted themes and analyses

16 patterns are retrieved from the information collected through in-depth interviews which are demonstrated in the Table … . These patterns are identified as sub-clusters. After categorizing the texts into 15 sub-clusters, each sub-cluster is separately analyzed.

Number	Sub-cluster	Number	Sub-cluster
1	Budgetary Challenges	**9**	Project Management
2	Compliance Challenges	**10**	Infrastructural Barriers
3	Suppliers	**11**	Technical
4	Projects Hurdles	**12**	Regulatory
5	Intermediaries	**13**	Providing Infrastructures
6	Interactions	**14**	Obligations
7	Data Integrity & Transparency	**15**	Benefits
8	Preventing misconduct	**16**	Practical Examples

TABLE 5. PATTERNS RETRIEVED FROM TRANSCRIPTIONS

1. **Budgetary Challenges:**

Based on the frequency of the answers, lack of appropriate financing of the projects by clients, which are all governmental companies, is one of the main problems. This inappropriateness manifests itself in late payments to the suppliers. This late payments, on the one hand, cause long delays in project deliveries and on the other hand, when they are accompanied with severe inflation and change of exchange rate in Iran, lead to increase in the costs of the projects. It could also happen that some vendors like the vendor of batteries which is mentioned by an interviewee, increase the price in a way that cover the risks of inflation and late payments. To be precise, the cashflow of the supply chains in Iran is not planned and this makes the delivery of the projects unforeseeable.

Another issue is the difficulties in working with international companies. Mostly, money transfer is not possible due to the sanctions. In some cases, contractors transfer money through some middlemen who do not work based on SWIFT. This again causes delays in payment and at the end delays in supplying goods for projects. Since most of the suppliers of the main equipments are international companies, the problems stems from sanctions cause huge difficulties in the field of supplying the goods needed by the projects.

Apart from the problems stems from delays in payments, there are also other problems relating to financial issues. One of these problems is dependency on some vendors. These vendors know that they are the only approved vendor which buyers should only work with them, therefore, they can raise their price unreasonably.

Another problems is that the contractors are not able to manage the budget they get properly. For example, one of the interviewees mentioned that SCADA system could be purchased as the last system and in one of their projects, it had been ordered before other systems with higher priorities.

2. Compliance Challenges:

The compulsion imposed on companies active in the supply chain of Iran's railway industry to comply with laws and regulations is divided into two categories. International laws and regulations and domestic regulations.

At the international level, Iran is now under severe sanctions from Western countries, which has heavy consequences on the supply of equipment and materials. Contractors cannot deal with well-known international companies that provide quality equipment. Even if, they enter a purchasing process, they may be deprived of some services like training, after sales services, guarantee, etc. In one case, the seller - Honeywell - failed to provide the dongle required for project delivery to the buyer - Mapna Railway Construction and Development Company, which caused the project to be delayed for a long time. This is a very serious problem that can affect the entire project and cause heavy losses to the contractors.

Another problem caused by sanctions is the inability of contractors to transfer money. There is hardly a solution found to mitigate the first effect of sanctions and contractors should substitute these high-quality providers with other less known companies. Of course, if some companies found on blockchain plattforms which are accepted by all the users, it also culd be a big help. For financial challenges caused by sanctions, the use of blockchain technology and digital currency may provide alternative financial channels that are less affected by sanctions.

At the domestic level, the challenges facing supply chains are problematic regulations, mainly related to customs clearance, and problems caused by forcing contractors to use domestic products, which creates monopolies. For example, some equipment requires testing to meet national

standards. With its documentation capabilities, blockchain can bypass the testing process required for customs clearance. Also, with subjecting the membership of suppliers in blockchain, it can force the suppliers to meet the minimum requirements and provide the approved documents. In this way, the quality of the supplied goods could increase.

3. **Suppliers**

Suppliers must comply with Iran's railway industry standards in order to be included in the list of clients' approved vendors. Also, contractors themselves have standards and suppliers must comply with these standards. Choosing suppliers that meet minimum requirements of this industry is very important to maintain quality in railway projects. The process of evaluating and convincing suppliers to meet these standards can be time-consuming. On the other hand, when it comes to bringing in new vendors who meet these standards and contractors want to replace old vendors with these quality vendors, it is challenging to convince clients—more specifically, the client's technical consultant. Blockchain's immutable and transparent platform can be used to keep records of certificates and compliance documents. The contractors as well as clients can refer to the documents existing in the blockchain which are reliable and in this way the process of approving new vendors becomes easier and faster.

Another challenge with suppliers is when they are unable to meet standards. Then the contractors have to change the specifications, which further leads to a drop in quality. Blockchain with data logging capability can store an auditable record of modified designs and specification changes. The data stored on this platform is reliable and users can transparently access the evaluation documents to ensure the quality of the supplied products.

Among other challenges facing the railway industry is the limited number of vendors for some equipment, such as DC busbars and switchboards. Also, finding reliable domestic sellers due to the effects of sanctions and supporting domestic industries is another challenge. A blockchain-based supplier network can connect rail projects with local suppliers and ensure they meet the required standards. Smart contracts can automate the internal supplier review process and accelerate their inclusion in the supply chain.

4. **Project Hurdles:**

Among the problems that relate to three pillars of every project, timing challenges including late procurement, changing the vendors and the time needed to adaot them, delays in delivery due to some difficulties like supplying spare parts, delays in payments, and changes in project timetables, can significantly impact project success. Blockchain technology can reduce the effects of escheduling through enabling real-time tracking of deliverables and procurement milestone. Additionally, Smart contracts can enforce deadlines and automatically adjust schedules to accommodate unforeseen circumstances.

Project delays along with some other problems such as lack of competition which leads to the increase in price by restricted vendors, late payment when there is inflation, shortage of basic materials which make the manufacturing process longer, etc. leads to increase in costs which is the second pillar of the project. Blockchain can help manage project finances by providing transparent records of costs and payments. Smart contracts can automate financial transactions and ensure timely payments and reduce financial risks.

As the third pillar, quality of the projects are also affected by some problems one of which is restriction of contractors to domestic products. As an example, the contractor of Tehran Metro Line 6 Project had to supply the clock and closed- circuit system from a domestic supplier. The quality was low and the contractor had difficulties in delivering the project because the quality was not approved by the client. In an international scale, the number of suppliers of some products such as DC switchgears is limited. This monopoly also leads to quality degradation and increasing the price. Blockchain's transparency can facilitate quality assurance by recording all changes, deviations and compliance certifications on an immutable ledger. Smart contracts can automate quality checks and approvals.

5. **Intermediaries:**

Existing intermediaries between buyers and sellers result in complexity in communications specially about technical aspects and may waste more energy, time and money. A shared platform like blockchain gives all parties the possibility to communicate safely and effectively .

Another problem caused by intermediaries is late payment since they use different types of payment methods which are not based on regular SWIFT codes. Blockchain can offer smart contracts to mitigate these delays. Smart contracts automate the payments and reduce the delays associated with late payments. In fact, blockchain introduces another payment method which could be even faster and safer.

6. **Interactions:**

Facilitating money transfers is one of the solutions mentioned by several interviewees. Under sanctions, the feature of using blockchain digital currencies in the future could play a big role in the transfer of money between international sellers and suppliers. Another benefit of blockchain is the possibility it gives to expand business and link to international markets. Companies can find and trust other companies more easily and constantly expand the chain. Communication between sellers and buyers becomes easier because there is a platform between them and they can access shared documents and contact them directly. Also, for companies that have done business with each other, records of technical and commercial interactions are available on the platform, which is another important feature of blockchain. Another point is that blockchain is based on terms agreed upon by all parties and is a good facility because it eliminates the need for long-term negotiations over the terms of contracts. As the last point mentioned, it allows

parties to rate other parties and acts like a rating system.Analysis: Blockchain can streamline vendor, contract, and project management by providing a secure and transparent platform for recording interactions and facilitating communication.

7. Data Integrity & Transparency:

Among all the features of blockchain in relation to data and information, transparency and traceability are mentioned the most. Through transparency, the buyer understands how the production process is progressing. Also, buyers can access the information of sub-suppliers to ensure the high quality of raw materials and parts. This transparent platform provides access to technical, financial and contractual information for everyone. Through traceability, buyers can track suppliers to ensure they are always sourcing their materials and components from approved, high-quality suppliers. Some suppliers outsource all or part of production to other companies, such as Chinese companies, to reduce costs, which can lead to reduced quality. Blockchain, with its traceability, allows buyers to track every moment of the production process and thus keep the quality of the ordered goods higher. Traceability can also prevent some unfounded claims. For example, when there is inflation, suppliers can claim due to changes in the price of raw materials, but if the dates of contracts and other contractual information such as payment dates are clearly recorded on the blockchain, the supplier cannot claim.

Security, decentralization and accessibility are other functions of blockchain. Security comes from data immutability. The data in the blockchain is tamper-proof, so it is reliable and provides more transparency and trust. Also, due to the security of the platform, payments can be made easily.

Records are shared among all platform users, giving them incredible access to the information they need. Knowledge management is a good advantage for blockchain members. They can see contacts and other sharable records for everyone to use in their projects. For example, with this information, they can predict and plan their future projects.

As other advantages, it is possible to track and view transactions in real time and encrypt data, which makes shared data more reliable and usable only for platform users.Access to Comprehensive Data:

8. Preventing misconduct:

With the transparency feature of blockchain, corruptions which are currently taking place will not occur or are limited. BC can be a tool for all sellers who want to sell their product in a fair competitive market. Currently there are vendors who are monopolists and other vendors cannot compete because of the advantage these vendors have or are given by government customers, even if their products are of higher quality and lower price. Through blockchain, these new sellers can be validated and become chain members as eligible suppliers. By bypassing the role

of intermediaries, BC reduces the supply time and thus the cost of projects. Both sellers and buyers in the supply chain can benefit from minimizing or eliminating the role of intermediaries. Also, reducing the number of dealers reduces the risk of fraud in purchases.

With the transparency and traceability that BC provides, smuggling of goods as well as under-declaration or mis-declaration at customs is prevented. And finally, it provides buyers with a means to refute false supplier claims. For example, one interviewee explained that one time a supplier claimed that he had bought parts at twice the price due to fluctuating rates and therefore the contract price had to be revised and modified. In a blockchain-based platform, we can track the process and find out what date the contract between our supplier and its sub-supplier was closed and what the exchange rate was at that time.

9. Project management:

BC can organize different aspects of a project and bring discipline to projects. Processes are simplified through smart contracts. Smart contracts also avoid lengthy negotiations and frequent meetings between sellers and buyers and transactions are done in a concise and reliable manner.

On a common platform, all stakeholders can track activities and view issues. Interaction between stakeholders becomes easier and facilitated, and they can work together simultaneously to solve problems in a timely manner. Also, smart contracts reduce the time of negotiations and contracting and causes to achieve common goals faster. Smart contracts also speed up financial interactions and transactions. Due to the transparency, the project steps are carried out easily and as a result the project delivery time is drastically reduced. In fact, BC acts as an automation system that mechanizes processes, thus shortening the time between production and delivery. Blockchain also promotes teamwork. Rather than using a waterfall approach, it makes the projects agile. Once you've taken a step, it's also easier to get client approval because the client is able to monitor the steps on a shared platform . All these consequences make the project more affordable.

BC affects not only the time and cost of projects, but also the quality. The quality of products and processes can be tracked throughout the supply chain. It causes quick detection and correction of defects and reduction of waste. BC is a platform that connects main customers (railway companies) to sub-suppliers. In this way, it is possible to ensure the quality of goods and equipment used in projects by monitoring the process and without the need for frequent inspections. It can also reduce the risk of non-compliance and avoid penalties for poor products. BC can also reduce the risk of outsourcing products to low-quality manufacturers such as some Chinese companies because all information related to the production of a specific product is recorded in the chain and is available.

10. Infrastructural barriers:

From the answers, it is clear that there is not a suitable infrastructure to implement the blockchain in Iran's railway industry. This infrastructure is related to the field of information technology, which lacks the required hardware and software. This problem exists even at the international level when companies from different countries want to use this common platform. There is also a lack of experts who are familiar with the concept of blockchain and how to implement it in the supply chain. The training of these professionals is necessary so that they can develop the application of BC. One interesting point mentioned about inconsistent infrastructure is the imbalance of infrastructure in a network of companies working together. Some of them use technological advancements and some of them don't hardly need a computer for their business. It is very difficult to integrate all these companies in BC to maximize the benefits of BC. Blockchain is based on the Internet of Things, and the IoT itself is also based on the Internet. In Iran, due to politics and security restrictions, we do not have high-speed Internet and 5G. As a result, we cannot properly collect data and develop the IoT.

One step before the establishment of BC is the need to increase the awareness of managers. Senior managers and decision-makers need to make sure that it will benefit them in the long run. Due to the unfamiliarity of the players, they resist any change towards implementation of BC in their area of management. It is especially seen in an old-fashioned industry such as the railway industry in Iran. Due to the complexity of this technology, a comprehensive and appropriate explanation of BC applications is essential.

Even after creating the BC platform, the work is not completely done. At this stage we need to define standards, rules and regulations and protocols not only at the national level but also at the international level among different businesses and several countries.

11. Technical barriers:

Blockchain technology is complex and expensive. A strong R&D team is required to develop it on the platform in a supply chain. It takes time to prove that it brings more efficiency and can make a difference, especially given the fact that implementing BC is expensive and requires investment in infrastructures. It is also problematic when BC cannot integrate with an existing ERP system, as they may not technically support them. Data immutability can be a disadvantage because once an incorrect data is placed in the chain, there is no way to correct it, or the correction will be too complicated. Another technical issue is that BC consumes energy, especially when the implementation scope becomes larger and must be applied to a large number of stakeholders.

12. Regulatory barriers:

Some companies resist disclosing data and sharing it on a common platform because their profits lie in ambiguity or lack of clarity. One of the main obstacles to the use of blockchain are this group that see their interests at risk. These are mainly intermediaries who are given privileges

through rules and regulations set by government agencies. This creates a monopoly for some companies. This is infact corruption that originates from the authorities. The state economy does not allow transparency in some processes because it may cause losses to some intermediaries. This transparency is essential in a free market and leads to free competition.

There are also regulatory concerns that need to be addressed before a blockchain-based platform can be created. All parties must agree on data security and confidentiality. Data privacy and security are especially needed in the railway industry as there is sensitive information in railway projects ranging from maintenance data to customer data. There is also data from railway design that should not be shared easily. It is very important to know which jurisdiction is applicable to resolve disputes on this platform. The parties should know how to resolve their disagreements and disputes before entering into a business on a new platform. For example, when a smart contract is hacked and funds are stolen, the parties need to know who is responsible and how they can take legal action to recover damages and settle contract fines. Especially in Iran, which suffers from lack of transparency and as a result lack of trust, this problem needs to be investigated and should be solved. A central supervisory authority is suggested by one of the interviewees, whose feasibility should be investigated. This central authority can also reduce the risk of 51%-attack, which can also be problematic if BC is implemented, and requires special attention in planning blockchain-based platforms.

A consensus is needed regarding share of data. There should be laws and regulations which protects all rights of all stakeholders. The parties should come to an agreement about sharing the information fairly. It could be the case that some holders of competitive advantages would not be willing to share their data and want to take the advantage of it even on a shared platform. For example by charging other participants. It is natural if they are afraid of misusing their valuable data and giving it to their competitors because they lose control of it once it is shared in the network. This needs setting protocols for giving them advantages for their valuable data as well as protect them by punishing those who cause leakage of data or misuse the data. As an example, one of the interviewees mentioned that 85% of the profit of the comes from supplying equipment and if the data of vendors are shared on the platform, it leads to downsizing the profit. This problem demotivates companies from being innovative because of sharing of their competitive advantage.

Consensus is needed on data sharing. There should be laws and regulations that protect the rights of all stakeholders. The parties must agree on a fair sharing of information. Some owners of competitive advantages may not want to share their data and want to use its advantage even on a common platform. For example, by charging other participants. It is natural for them to be afraid of misusing their valuable data and giving it to their competitors because once it is shared on the network, they lose control over it. This requires setting up protocols to benefit their valuable data as well as protect it by punishing those who cause data leakage or data misuse. For

example, one of the interviewees stated that 85% of the profit comes from the supply of equipment, and if the data of the sellers is shared on the platform, it will lead to a decrease in profit because other competitors can have access to high quality products with lower prices. This problem discourages companies from being innovative because of sharing their competitive advantage. Some companies have some internal regulations and protocols that does not allow them to pass data which causes implementation of BC more difficult and restricted.

There are no relevant laws or regulations in Iran that facilitate the implementation of blockchain. On the other hand, there are some prohibitive rules. For example, there are rules against using smart contracts to conduct business. The same rule exists to prevent the use of digital currencies in financial transactions. There is also a general rule in the railway industry that prohibits programs, applications and software developed in countries hostile to Iran, such as the United States and the United Kingdom. Finally, there is the issue of sanctions imposed against Iran, which limit transactions with Iranian companies. This law prohibits international companies from cooperating in a platform where Iranian companies are a part of.

13. Providing infrastructures:

It is not surprising to see that stakeholders in the supply chain are not aligned with those who want to implement blockchain to improve processes in the supply chain. This is because they need to learn about BC and see exactly how it works and how it is implemented. The advantages and disadvantages of BC should be introduced and explained to them. To convince stakeholders, we need to educate them. Training is part of the persuasion process and training courses should be held for experts and managers. Especially the younger generations should be educated and a positive culture should be created to use BC. In this way, the fear of some companies that use traditional methods can be reduced. It is suggested that the BC be thoroughly explained to a group of stakeholders so that they can talk to each other and discuss the ins and outs before forming a common platform.

14. Obligation:

Two factors can be effective in the application of new technologies in a particular industry or field of study. These two are market-pull and techno-push. In the case of BC, there is no market traction due to the industry's unfamiliarity with this technology and lack of infrastructure. As a result, the factor that can be used is techno-push. According to Techno-push, BC should be introduced to companies and experts should be trained. But this is not enough and an external agent must force companies to apply it. This representative can be a large company such as Mapna Group, which can set regulations for its suppliers to work on the blockchain platform. Mapna Group can advance this technology because it has a large market share. In fact, if such companies do not compel their suppliers, there will be no blockchain in the supply chain. Since

the entire chain must cooperate on this platform, the company that is the biggest market leader and has the largest market share is the best to push other companies to use it.

15. Benefits:

This technology should be defined for the stakeholders as a reliable and useful tool that not only causes financial benefit, but also brings about technical improvement in the processes. Stakeholders should know that BC can help them financially although it is costly at first. It is a one-time investment and then there is the picking and benefiting phase. In an organized plan, the usefulness of BC in the long run should be explained to them. To provide an example to prove the benefits of BC, one of the interviewees gave the example where BC can help product buyers find the root of technical problems as follows. A contractor purchases a control cabinet that contains many components. When an error occurs in such a product, the buyer must know where the root of the problem lies. In other words, which component is defective and causes the problem. This is done by tracking the parts and finding out which part is not of high quality and where the defect is.

16. Practical examples

One useful way to demonstrate the usefulness and profitability of BC in SC is to provide stakeholders with practical examples where BC is applied in a specific sector. Also, due to the newness of this technology in Iran, it is impossible to use blockchain technology in the entire sector, such as the supply chain of the railway industry. Therefore, instead of making a big change and transforming the entire supply chain platform, it is suggested to apply a single BC feature such as traceability in a small part such as shipping in order to track delivery. When the result is visible and satisfactory, stakeholders may decide to expand it to other features step by step and implement other features of blockchain technology. It is necessary to create infrastructure and culture to accept new technologies by seeing its benefits.

5 DISCUSSION

This study was undertaken to uncover and analyze the main issues that plague the supply chain of the rail industry in Iran and also investigate the role of blockchain technology in addressing these issues. Several interesting facts were learned from experts and managers of Iran's railway sector during the interviews, which helped me to better understand what the main problems are and where these problems originate from. Also, what are the challenges and solutions of these challenges regarding the implementation of this technology. Through conducting literature review, this research has revealed similarities and disparities through a comprehensive review of relevant literature. It is clear that while some themes have global resonance beyond national borders, there are distinct challenges that are unique to the Iranian industry that create special challenges. These challenges are rooted in the specific political dynamics and infrastructure conditions of Iran.

Findings from Literature Review:

Before diving into the empirical part to gain new insights through in-depth interviews with experienced experts in this industry, I conducted a comprehensive review of the existing literature on the supply chain challenges in the transport and logistics sector in general and in the railway industry in particular, and also the possible applications of blockchain technology to address these challenges. The literature review revealed several important findings, which I describe below.

From what I found, it's clear that the great potential of blockchain has been discussed more in theory than in practice, and it still has a long way to go before it reaches its peak and be used in various industries (Astarita et al., 2020). Blockchain can positively impact supply chain performance and lead to greater customer satisfaction and supply chain efficiency by increasing transparency. (Lee & Zhang, 2023). Decentralization through blockchain helps transfer from a centralized network to a platform shared by all parties where everyone can conduct business and monitor changes (Iman Bashir, 2018). Data security in a network of stakeholders is increased by storing the entire blockchain in a large number of nodes and simultaneously verifying transactions and calculating new blocks using miners (Jostock, 2019; Schlatt et al., 2016). Vendor selection and supplier development, materials management and inbound logistics, internal production and operations, cross-border logistics and marketing, and reverse logistics to create a sustainable and green supply chain are activities that become easier after blockchain implementation (Dutta et al, 2020). The origin of the commodity as well as its sustainability status can be traced and tracked by stakeholders throughout its life cycle using a decentralized ledger.

Smart contracts are predefined automatic transactions that are introduced in order to perform and control the flow of documents in contracts (Pournader et al., 2020). As the first and so far the most important application of blockchain that does not require an intermediary company such as a bank or financial institution, Bitcoin plays a fundamental role in transactions between nodes, providing users with decentralized, secure and universal digital cash system (Verma, 2020). Compared to a traditional software solution, smart contracts offer effectiveness, accuracy, accountability, integrity, fraud resistance, uniformity, interoperability, and more. The most outstanding effects of the smart contracts are: self-sufficiency, absence of intermediaries and non-physicality (Ghode et al., 2022).
Blockchain provides a powerful platform for many businesses to optimize their project management (PM), which helps them not only eliminate cost overruns and delays, but also improve process efficiency.

In Iran, supply chain faces many challenges, for example, international sanctions set by United States that prevent many companies cooperating with companies in Iran. In 2018, Siemens, a German company, announced that it will not work any more in common projects in Iran because of sanctions. Also, Stadler Rail, a Swiss firm, announced that it too will be ditching projects, such as the $1.4 billion railway deal that included building and delivering 960 subway cars to Iran. (Caspian News, Iranian Railway Projects in Jeopardy of Being Canned, Due to Trump's Sanctions, August 6 2018, access date 09.09.2023). There are also some other challenges in terms of implementation of new technologies in Iran, including prohibitive laws and regulations, lack of technological infrastructures, lack of knowledgeable experts, costs of implementing new technologies, data security concerns, and the increasing rate of data growth (shamizanjani, 2020).

Findings from Interviews: Based on the findings and concepts I extracted from the literature review, an interview was designed to be conducted with the participation of key stakeholders in the railway industry, including supply chain managers, logistics providers and government officials. The interviews unveiled nuanced insights specific to the Iranian railway context. Participants highlighted the significant impact of political factors such as trade sanctions and government regulations on supply chain operations and underscored the unique challenges facing this region. Additionally, I found that while the potential benefits of blockchain were acknowledged, privacy and network scalability concerns emerged as barriers to its widespread adoption.

Iran's railway industry supply chain activists are facing many challenges and problems. For example, due to lack of funding or its mismanagement, contractors in Iran who are fully engaged in government projects suffer from proper financing of projects. Delay in payment to general contractors of the railway industry in Iran leads to delay in payment to sub-suppliers. As a result, products are produced with great delay. Considering the high inflation rate in Iran on the one hand and project overhead on the other hand, this leads to an increase in the cost price of the projects. Another main problem is in the supplier discussion, which includes three different

types of problems. The first problem is finding quality vendors who are willing to start or continue working with Iranian partners and do not want to comply with the sanctions imposed on Iranian industry. The second problem is that the suppliers willing to operate in this industry are usually new and lower quality players who sometimes need to change their standards to match the standards of the railway industry in Iran. The third problem of suppliers is the monopoly caused by the government's support for domestic production, which leads to the dependence of projects on them and the lack of commitment to improving quality and stopping price increases. All these problems have a negative impact on the three main pillars of projects including time, cost and quality. Another big problem is the role of middlemen in Iran who do not allow the change of regulations towards the use of BC technology because it is against their interests.

When blockchain is implemented, it will bring many solutions to the industry, the most prominent of which are facilitating interactions, preventing misconduct, and improving project management. Interaction between international as well as domestic companies will be easier than ever, as BC is a platform for transferring money, speeding up processes through mechanization (for example using smart contracts) and connecting to quality suppliers. Transparency and traceability in SC will be increased using this new technology and misconduct can be prevented as a result of that. The traditional model of project management with high bureaucracy and paperwork is currently used in most industries in Iran, which causes problems in the path of modern project management. With the possibility of having a common platform, agile project management becomes possible.

The obstacles to implementing BC are almost innumerable, making large-scale application of this technology very difficult. These obstacles arise from a lack of infrastructure, technical barriers and regulatory obstacles. An important reason why there is little investment in this area and, on the contrary, there are restrictive laws and regulations is that most of the industry in Iran is regulated by the state. Therefore, there is neither the need nor the inclination to take immediate action to develop this new technology.

To convince stakeholders to adopt the technology, they must first be trained and exposed to this technology. Without knowing the pros and cons of BC, it is impossible to convince them, as implementing this technology requires major changes in current systems and processes. Showcasing the benefits of this technology in a way that proves its profitability, as well as showcasing successful projects, are the measures that can be taken to convince decision-makers to embark on this major change.

Integration and Synthesis: Comparison of findings through literature review and semi-structured expert interviews sheds light on the different perspectives existing in the subject of study in an international level and in a domestic level in Iran. While in the literature review section, I tried to find general problems and solutions facing this industry and the BC solutions for it, the research interview section examines the issue in detail in Iran.

Comparing the results through literature review and semi-structured expert interviews sheds light on the different perspectives that exist in the field of study at the international level and at the national level in Iran. While in the Literature Review section I tried to find common problems and solutions faced by this industry and the BC solutions to them, the Research Discussions section examines the problem in Iran in detail.

The results of our empirical research highlight a difference in the nature and severity of challenges and issues in the rail industry supply chain in Iran and the need for tailored blockchain solutions that take into account the existing political and infrastructural conditions specific to Iran. These findings not only contribute to a deeper understanding of the challenges, but also highlight opportunities for targeted interventions and policy adjustments. The convergence of literature-based knowledge and empirically based insights highlights the importance of a holistic approach in addressing supply chain issues in the rail industry and effectively implementing blockchain solutions.

A quick look at Figure 12, which is a word cloud of the total information extracted, reveals some particular differences between these two contexts, with the main issue in Iran being project delays. Sanctions follow, and then cost overruns, security and privacy concerns, and transparency and financial issues. Although some of the points appear in both literature reviews and interview texts in these two contexts (international level and domestic level), such as the transparency function of blockchain, security and privacy concerns, and lack of knowledge, there are points that can be uniquely discussed in the context of supply chain industry and blockchain implementation in Iran or the degree of their importance is different in these two contexts. Some of these differences are as follows.

Project Delays

Project delays are the most frequently mentioned topic in the concept of this research and represent a major problem and challenge in railway projects in Iran. Of course, this problem already exists at the international level and one of the goals of BC is to solve this problem through smart contracts, real-time monitoring and facilitation of interactions, but the significance of these issues is different in these two contexts. The reason for this is that in addition to the general problems that exist on each platform, there are some causes such as restrictive rules and regulations, budget constraints and inadequate funding of the projects, sanctions and existing intermediaries that lead to major delays in projects.

Cost Overruns

This issue is barely mentioned in the secondary data I examined for this research. The main reason for cost overruns, as mentioned in interviews, is project delays, which are accompanied by

inflation and increasing project overhead costs. Another reason for this is that due to the sanctions and the regulation to protect domestic products that only apply in Iran, suppliers who do not see themselves in a competitive market tend to increase prices.

Quality of the projects

Due to the sanctions and the Domestic Products Protection Law, on the one hand, which lead to a limitation on the number of suppliers, and the attempt to keep the cost of the projects lower to compensate for costs caused by delays, on the other hand, the quality of the products decrease and as a result the quality of the Whole project decreases.

Budgetory Challenges

Railway projects in Iran are financed by the state. Due to the lack of budget or lower spending priority in the railway sector, the defined projects face payment difficulties to their suppliers. This leads to a failure cycle with long delays, lower quality and cost overruns. Late payments lead to large delays and large delays lead to cost overruns. Late payments also result in the quality suppliers refusing to cooperate with Iranian contractors, leading to a deterioration in the quality of the projects. This budgetary challenge does not exist in the systems that already use blockchain, because to provide a platform for the application of BC, one of the conditions is to secure budgets.

Payment Through Blockchain

Payment with cryptocurrencies is another area that distinguishes conditions in Iran from those at the international level. Due to sanctions, banks in other countries are unable to transact with Iran, and payment via cryptocurrencies can solve this problem. However, there are rules and regulations in Iran that do not allow the use of cryptocurrencies for payments. The reason for this is mainly the lack of trust in this system and the loss of control over the money, although the protection of banks as intermediaries is also one of the main reasons.

Sustainable supply chain

Although discussions are omitted from the interviews, inventory management and maintaining sustainability are important topics in supply chains. These two topics are not mentioned by the respondents. As far as sustainability is concerned, it is more of a new topic and it is now clear that the experts have not yet dealt with it. As for inventory, while it makes a big difference, it is rarely highlighted as an area where blockchain can help.

Link between BC and other technologies

One aspect that is not highlighted in interviews and is very important if a system wants to apply SC is the connection between BC and other technologies such as IoT, GPS, AI, etc. I think the

players in the rail industry supply chain are only aware of the problems that exist in their area of activity and, based on the blockchain study, know the possible uses of BC to address these problems. Since no pilot project has been defined to study the use of blockchain in this industry, they hardly have a clear idea of what problems might arise when implementing it in practice.

Fighting Corruption

The problem of corruption in government bodies is constitutionally anchored. The transparency of blockchain technology can help in the fight against corruption, but for it to be successful it needs strong political will to support it. This requires figuring out how to use blockchain to increase openness and trust while maintaining proper system governance.

Cutting-edge customs options

One of the most intriguing suggestions was the use of blockchain in customs processes that I saw one of the most interesting technical outputs of this research. This could streamline customs procedures, result in cost savings, and improve supply chain efficiency. We must determine whether this concept is feasible and how it would function in real life. Like the issue of testing sensitive products in customs, we can consider using blockchain as a source of reliable documents which eliminates our need for further tests at customs because the records of previous tests could be shared on the blockchain.

6 IMPLICATIONS FOR RELEVANT STAKEHOLDERS

Like any other new technology or strategy that should be introduced and implemented, the implementation of BC technology primarily requires supporting rules and regulations. The major players and beneficiaries of this technology should call on the government to change the restrictive rules and establish new rules that facilitate the use of this technology. As described in the text, this is currently a major problem and requires a major change in the system. This requires the government to take steps to curb corruption and invest in technology, education and infrastructure. The railway industry is an old branch in Iran, so the new generations should be given the opportunity to develop this technology and a new culture should be built in various areas of the industry. Rail industry managers should consider developing a strategic plan for developing blockchain technology. This plan should include the steps and measures required to integrate blockchain into the supply chain processes. They should establish key performance indicators (KPIs) to track the impact of blockchain adoption on supply chain efficiency and profitability of the processes. After establishing, they should regularly assess the success of blockchain initiatives using these KPIs .

One of the key concerns of stakeholders is the inappropriate and unfair access to competitive advantages and power. In other words, a protocol should be defined that gives companies an advantage in proportion to their contribution. With current protocols and standards, some parties may lose their competitive advantages and some of them take more than they bring in. A managerial implication should be to strike a balance in this regard.

Another managerial implication, especially in the government sector in Iran, is to set up pilot projects to test the idea, identify the shortcomings and correct these shortcomings and demonstrate their benefits. Additionally, big players can promote this technology by forcing their partners to use a common BC-based platform. Managers should prioritize investments in blockchain solutions for specific supply chain areas where they can provide the greatest benefits. Conducting a cost-benefit analysis can help identify the areas with the highest ROI. Finally, they should encourage a long-term perspective when adopting blockchain, recognizing that the technology can evolve over time. They should stay informed about new trends and possible improvements to blockchain solutions.

7 FUTURE RESEARCH

Because of nuance of this technology in the field of study of this research, so much researches in the future should be done. Even in an international level, not all the aspects and ambiguities engaged with them are clear, let alone in Iran. This is quite a complicated field of study and involves so many aspects from technical and regulatory aspects to financing and standardization. The first research that should be done futurewise should be about defining rules and regulations in order to change the current methods and switch to the new systems. To do so, successful implementation of blockchains can be studied in order to use the lesson learned and successful experiences. Another necessary field of research is investigationg how to benefit stakeholders in a fairly manners. This should cause all the stakeholders benefit the most and some stakeholders do not lose their competitive advantage and as a result their motivation to participate. Standards and protocols should be other field of future study, where facilitating the use of blockchain needs standards and protocols that on the one hand are defined based on the domestic conditions and on the other hand comply international protocols. Security and privacy in this context is really important as it is about sharing and using information. So, maintaining a secure platform on which the stakeholders do not have concerns about misuse of information and destroying their data privacy, is another field that needs more attention and investigation. Futurewise, in order to improve efficiency of the chains, there would be a need to measure the KPIs and see the results of implementation of blockchain quantitatively which defines another field of future research. This technology needs to be linked with other technological advances. So, the developers should study more about linking this technology with other technologies such as IoT, AI, RFID, etc. Finally, every system and business needs to comply with sustainability policies in order to help the societies to be sustainable in the long run and railway industry in Iran should investigate how it can move towards a sustainable business by using blockchain technology.

Due to the nuances of this technology in the study area of this research, much more research should be conducted in the future. Even at the international level, not all the related aspects and ambiguities are clear, especially not in Iran. This is quite a complicated area of study and involves so many aspects, from technical and regulatory aspects to financing and standardization. The first research area in the future should be about defining rules and regulations to change the current methods and move to the new systems. The successful implementation of blockchains can be examined in order to use the insights and success experiences gained from them. Another necessary area of research is examining how to help stakeholders in a fair manner. This should ensure that all stakeholders benefit the most and that some stakeholders do not lose their competitive advantage and thus their motivation to participate. Standards and protocols should be another area of future study, with facilitating the use of blockchain requiring standards and protocols that are defined based on domestic conditions on the one hand and

consistent with international protocols on the other. Security and data protection are very important in this context as it involves the exchange and use of information. Therefore, maintaining a secure platform where stakeholders have no concerns about misuse of information and destruction of their privacy is another area that requires more attention and investigation. In order to improve the efficiency of the chains, the KPIs would have to be measured in the future and the results of blockchain implementation would have to be looked at quantitatively, which represents another area of future research. This technology needs to be linked to other technological advances. Therefore, developers should look more closely at linking this technology with other technologies such as IoT, AI, RFID, etc. Finally, every system and company must adhere to sustainability guidelines to help societies be sustainable in the long term. The rail and rail industry in Iran should explore how it can transition to a sustainable business by using blockchain technology.

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APPENDICES:

Appendix 1: Interview Guideline/Questions

This interview is designed to gather information from 15 anonymous experts in the supply chain management field. The interviewees are mainly managers or senior experts from various fields, including procurement managers, procurement engineers, project managers, planning managers, project control managers, and logistics staff. The purpose of this study is to understand the challenges and best practices in managing the supply chain of railway constructional projects implementing Blockchain technology. The methodology will be used to collect and analyze the data includes preliminary data review, in-depth open-ended interviews, and content analysis.

Interview Guideline

Introduction:

Interview begins by introducing myself, explaining the purpose of the study, and providing assurances that all interviewees' identities will remain anonymous.

Background Information:

Asking the interviewee about their experience in the field of supply chain management for railway projects, including their roles, responsibilities, and the projects they have worked on.

Interview questions:

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

1.2- What are the biggest challenges in the supply chain of railway construction projects?

1.3- How do these challenges impact the overall success of railway construction projects?

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

2. The role of blockchain technology to address the problems and improve efficiency:

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

3. The barriers of implementing blockchain technology in the railway industry:

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

Closing:

Interview ends by thanking the interviewee for their time and insights, and reiterating the confidentiality of the interview.

Methodology:

To gather data for this study, a preliminary literature review will be conducted to understand the challenges and best practices in managing the supply chain. The study also involves in-depth, open-ended interviews with 15 anonymous experts who have experience in the field. The interviewees are mainly managers or senior experts from various fields, including procurement managers, procurement engineers, project managers, planning managers, project control managers, and logistics staff. Due to their conservatism and some employment consideration, the interviewees want to remain anonymous.

To analyze the data collected and take a result, content analysis software will be used to identify patterns and themes in the interview transcripts. The software utilizes text mining and finding algorithm, which will help to identify commonalities and themes in the interview data.

Appendix 2: Interview Transcription

1- AKM Online 11.06.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I am an electrical engineer and work in Engineering department. I provide the projects with technical specifications. Also, I investigate the claims of supplier. At the same time, I follow the production process with participating in Production line inspection, Factory acceptance tests and installation and commissioning.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

One is choosing suppliers. There are some suppliers that are not compliant with our standards. There are suppliers that we needed to ask them to meet the highest standards to be able to bring them to our vendor list. I think the biggest challenge was complying with our standards.

1.3- How do these challenges impact the overall success of railway construction projects?

When it comes to the success of the projects, I would say the time wise. These kind of challenges are going to impact the overall success of the project. When we are not able to get the projects on site as the day they supposed to ship the product, you are kind of overseeding the time. So, in the big picture, we are not going to complete the projects in a timely manner. That is a very big issue to me. I usually look at everything in a project perspective. As a result, the money, time and MOV are very important things we need to deal with. When you are not satisfying customers, so you are not able to completing the project. I would say cost wise, timewise impacting the success of the projects.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

I need to think about it. (Question: Should it be specifically about railway projects?/ Answer: Yes, for example your experience about Tehran Metro Line 6 projects or Isfahan Metro line 2). Yes, I recall the time that we were evaluating the suppliers for some LV Panels and we had a hard tike finding the supplier to provide us with the full compliant, the certificate for us to put them in our vendor list. So, we had to go with other vendors that were not in the list of our client. We went through a lot to convince the Metro to accept them at their vendor list. So, we had to pay a lot of money in order to convince the supplier. We had to go through a big process; give them a tour for signing some kind of agreement them. Just give them the crazy warranty to make them sure if something happened to the projects. We are the one who is going to pay all the costs and delays if they occurred.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I mean; My knowledge about the blockchain is not that vast. I heared that during the time cryptocurrency was kind of popular and everyone is talking about blockchain and cryptocurrency and how they build the cryptocurrency and the fact that crypto currency is build on blockchain technology. My knowledge is not that big. Just a medium knowledge like ordinary people.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

Based on what I learned about blockchain, I would like the people in USA usually say so good to be true. It is kind of like bullet proof. The skeen that is going to improve the supply chain process a lot. To me everythings would be superorganized and super disciplined and it is going to facilitate all aspects of the supply chain, not only just one aspect. From the start to the end, even for people who are working in Engineering Department. Because they are super detailed. When it comes to design of something, they have to make sure that everything is on the basis that all parties are agreed upon. I would say. It is going to change the whole world of supply chain a lot.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

To me, picking a supplier. An engineer cares about working with a good supplier. Since there is a very well-desingned way of working, I would say picking suppliers.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

That is the thing. When you are introducing a new technology to an old- fashioned industry, it is very hard to convince people to get along people. Changing the people's way of thinking is super hard. And also, you have to train them. Some people in railway industry do not want to change anything. They just go with the way they have been working with it. So, there is no need to change anything that has been working. So, convincing those narrow-minded and silid- minded is very hard. And also, there is no expert in blockchain technology. As far as I know, this is a super new concept in industry. You are going to let them to think for a while, so that you can see what is going to be the bad consequences of this technology to apply in this industry.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

I would say convincing the top managers or the top guns. And another one, since everything is all about money. I am not sure how much we are going to spend in order to implement the technology to supply chain. Are we talking about a big money. We have to have a business plan. Showing that this technology is going to improve us money wise. It is one time spending money and afterwards, we are picking and drawing some products from it. It is just a tradeoff. I would say the biggest barrier is just convincing people and making sure this technology is not going to cost us a fortune.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

Yes. I think the cyber security is going to be a big challenge for Blockchain in order to be implemented. Right now, because of the relationships that the big countries like China, USA and European Union and Russia. Cyber security is a big deal. I am not sure there is a regulatory or legal aspects in this regard. (Comment from interviewer: I mean in Iran. Do you recall a regulation?). About Iran I cannot recall a regulation or law.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

Having a plan. There is a term in this regard that I cannot recall. You are going to have the tradeoff plan showing that these are the benefits of implementing Blockchain. This a the must have thing that we have to have to convince stakeholders and also definitely definitely the training. That is part of convincing the stakeholders. We should bring them on the same page we are.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

You know; My knowledge about Blockchain is not that much, but the thing is I know in many companies there is a section and there is a change department. I am not sure if that change department is going to be part of this data privacy stuff, but as far as I know, when you define something, it is going to be solid. No matter what. So, in order to adupting this technology to change department, I do not know how these kinds of things are going to work. But security wise and privacy wise, I feel like the Blockchain is kind of to my knowledge is super secure. Nothing is perfect. I am pretty sure there are some holes in this technology. You should give it time to find those holes and also, we can just find some solutions for. To me it is not a big issue. It is not something that no one can address it. Definitely it is going to exist some concerns about privacy, but they are addressable by these IT experts.

2- MM- Online Interview Sonntag 28 May.

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects.

I am a commercial expert who works in a company which is an EPC contractor, and we work in railway industry as General Contractor. We get into the tenders which attend to railway industries, and I am the procurement engineer who buys all goods and materials for these projects.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

If I should name the biggest one, it would be difficult but there are several challenges in our supply chain process. We face to several issues like financial issues and delivery times and some governmental rules in the country. As I can recognize these three are the biggest ones.

1.3- How do these challenges impact the overall success of railway construction projects?

First of all, finance issues. As you may know, when we are going to purchase goods, we need money, because our suppliers need money to finance their products. We need to settle down payment or retainment for helping them to produce or manufacture our required goods. Also, because of some issues like international sanctions in our country, we face a big issue called delivery time. Many times, we are waiting for importing critical part of our equipment to get into the manufacturer to produce final goods. So, delivery time which will be affected by several issues is our main concern. Also, as I told you at first, we have several limited rules from our government side. The biggest one is custom clearance related rules. When we need to import some high technological final products, we should face a big challenge in our custom clearance ports. So, these three big issues affect the milestone of the projects. We will face in the progress of a project, when we agreed before with the final end-user that we should finish any projects within two and a half months, when we face these issues that I named, maybe we face to serious delay in the progress of a project.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

Yes. Sure! Last year we agreed with End-user, I mean Tehran Railway Company. We agreed to finish 6 stations of Metro Line 6. We planned 6 months ago and placed an order for supplying goods for the projects. But, according to those serious challenges that I mentioned, we went to serious delays and penalties in our agreement. So, we have been delayed, I think one month. We finished the project one months later than the milestone that we agreed with the client.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am familiar to some extent. I have read one or two essays and also, I have watched some videos about it.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

I think it will affect a good way. You know, in our country, we have a big government. So, this big government involves in any projects. Even small projects. When government do not let private companies to do projects themselves, it is a little hard to use Blockchain. But, if I say overall, Blockchain itself because of it's transparenca, because of its clearance, it helps someone like me who is worried abour supply chain progress. I believe that Blockchain will help to have clear supply chain browse and will help to. As I know in Blockchain, you have access to every littke information or every little bit of data of supply chain. So, when everything is clear, everything is in hand, no matter, you are which part of supply chain. When everything is clear, you can be aware about any penalties or any issues that will appear in supply chain and you face them. As I believe, since Blockchain clears the process of supplying, it will be helpful.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

Let me think! You know, as I told you, I believe in using Blockchain because it helps to clear every single part of supply chain to be useful. As I face this issue in my job, when you do not know about the suppliers of your supplier's issues, so you cannot be ready for issues that will occur in supply chain later. I think Blockchain itself because of its specific character which is it's transparency, it will be a major impact.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

(Question: You are talking about linitations/ Answer: Also, drawbacks). You know, honestly speaking, I am not using it and do not know an organization using it. So, it is difficult to answer this question because any new method works in several areas and then you can see that there is any negative impact or something like this. Generally, and in theory, I think it will be a helpful tool for supply chain. (Question: What about limitations). I explained before. (Q: Are there any other limitations). I do not think so. My big concern is the government. But, if our companies, I mean our private companies know about the advantages of Blockchain in supply chain. It will be helpful. So, I think there is only one limitation of using Blockchain in supply chain which is governmental rules. We have another idea in commercial activities. It is free market. In free market, even you have clear connections and transactions, it will be helpful to expand free market. But, when the government enter a market, it does not like to have transparency and clearness.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

Only governmental interference into the free market.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

As I know, we may have many requirements in our market to use Blockchain. So, there is no concerns about using Blockchain in supply chain. Even in railway industry or somewhere else.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

You know, whenever not for using Blockchain, every time when you want to start a new process or new business or new issue at all, you will face some challenges. You will face some limitations. One of them, maybe would be their knowledge about Blockchain. Somehow, it would stakeholder's benefits. Somebody or some businesses or some companies which are required to use Blockchain. They like to hide some data. Because their benefit is in ambiguity. As I explained before, Blockchain helps you to clear any part of supply chain. So, against this biggest character of Blockchain, some companies or some stakeholder's benefits will be jeopardized. (Q: Do you mean they lose their competitive advantage or you mean their costs are higher than benefits? / Answer: Yes, sure! Both of them)

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

As I told you, I believe in free market everywhere. When you have free market, when you work in free market, the privacy of data is not the main concern. Free market helps you to reduce delivery time, it helps you to reduce final costs, helps you to know new technological companies, any new part of supply chain. I think privacy of data is just only one concern about those companies that I said before. They do not like to lose their benefit. So, with hiding data, they keep their benefits. If you reveal data in Blockchain, the benefits which are not fair, you will affect their benefits.

3- MS-online 29.05.2023 10:58 a.m.

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I work as a planner and project control expert in one of the railway projects.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

From a planner's perspective, the biggest challenge is project time. The time allotted for a project is limited due to time constraints in railway projects. These projects must be done in a certain time with a certain budget. But, due to the problems in the field of equipment supply, this time is longer and imposed a lot of additional costs on the project. Well, for all these things, you have to increase your period of need, and this will make all your expenses multiply.

1.3- How do these challenges impact the overall success of railway construction projects?

When the project time increases, it causes you to incur a lot of side costs including the cost of human resources and the cost of equipment which is needed periodically for maintenance of a project, the cost of facilities provided for the project for a specific period of time

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

In the last project I worked on, we had a big delay due to the delays occurred in supplying equipment and materials. These delays were accompanied by a severe inflation in the price of the equipment and caused us to completely change the contract and choose a new contract because it was not cost-effective for the client. This means that instead of the contract being extended, a new contract was signed. It caused severe losses for the client as well as for us as EPC contractor.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am familiar with this technology in terms of cryptocurrencies. I know that it has strong points and focuses on some aspects. It is used as a base because of its transparency, decentralization, security, and its immutability. This immutability can be both positive and negative. (Q: Can you elaborate? / Answer: Let us go ahead and we will discuss it further.)

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

I noted some points down. The transparency that it provides in transactions. When you want to supply materials and equipment, you can track this process. Stakeholders can track this process. It is a point that leads to efficiency of the project. Those who are involved

in the project can track and assess the process step by step. Also, a decentralized platform is created between the customer and the supplier with that the process of supply and payment can be facilitated. Another point that we can mention is documentations like technical documents, specifications, permissions, and contracts. Blockchain can help us in document management. As I mentioned before, it can help us facilitating in payments and financial processes and provide us with a secure platform. And on top of that, it can boost the teamwork in a project. It means that instead of waterfall method, it uses agile project management method. It means, instead of finishing one step and getting the approval of the client, this approval could be obtained while this step is being currently done. As a result, it is an effective tool for project management.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

I think one of the biggest impacts it could have on supply chain process is facilitating financial affairs and the fact that it makes this affair secure. In a very clear manner, all the stakeholders can see these transactions. Another issue is transaction and movement of goods that is traceable by all the stakeholders. If I want to mention other points, I can say vendor management, contract management and project management can be done efficiently inside the supply chain.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

Again, it has positive aspects as well as negative ones. A negative point is the security of data as well as privacy. Specially since there are sensitive information in railway projects from maintenance record to customer data and also a part of design which could be controversial. An agreement should be reached by all parties about the data and security of the data could be one of the risks relating Blockchain.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

One of the biggest hurdles is standardization of protocols and policies, especially when implementing Blockchain is needed to be done, it is done among some countries, and it needs a common policy among these countries. In fact, Blockchain integrates the processes in different countries and these countries have their own policies and regulations. And we can mention the data privacy issue. For example, when you are working in China it could be so different than you are working in USA.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

Because I did not have the experience myself, I do not know any regulation. But, as I told, smart contracts cannot be done in Iran. There are laws that say the smart contracts could not be implemented. And because of the existing sanctions, the clarity of these transactions could not be reached because of these limitations. And Also, there is limit on the transactions because of these sanctions.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

Well. It is certainly very difficult because this process is costly. We should explain this technology elaborately and convince them that this technology in the long run could be very helpful. When you do smart contract management, it means the process is being done paperless. It could be beneficial for the nature and moneywise it is beneficial for them. It could help the process being done very time effective, the fact that all the stakeholders can at the same time track and participate in doing the steps. The project is being done agile and all the stakeholders are able contribute during the steps and they can modify and correct the process at the same time, and it helps since the wrong process could be prevented before it leads to a great loss because of agile project management.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

Well, with involving network expert and I do not have this knowledge. But currently so many transactions are being done throughout the world and they are very secure. Certainly, we can do these transactions in a secure platform and take the advantage out of it.

4- AB-online 29.05.2023 16:00

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I am the Commercial Manager of MRC which is active in the railway industry. I oversee supplying goods and services in a timely and cost-efficiently manner.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

Currently, international problems caused by sanctions, money transfer issues, and limiting domestic regulations which partly indicates the limit in countries monetary resources. This limitation causes the cooperation between Iran and top internationally renowned brands be very limited and, in some cases, impossible.

1.3- How do these challenges impact the overall success of railway construction projects?

Since our relations with other stakeholders are not based on international protocols and conventional relations (unlike two European countries, for example) and due to specific geographical and political conditions, our work is very difficult in terms of relations with other countries. It significantly increases the time and cost of the project.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

This has happened many times when our money is transferred to Europe. While these money transfers can be done in one day, due to sanctions there are middlemen in between, some of which do not work based on SWIFT. Each of these intermediaries has its own method and solution. These different methods cause us to have a long delay in transferring money. In the case of Secheron equipment as you are familiar with, these delays resulted in the amount being 40-45 days on the way to the supplier's account. We even experienced one case where the money was transferred, but Sechron could not withdraw the money due to sanctions issues and it took 6 months to reach them.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I have been hearing about it for almost 4 years and have been familiar with it for about two years. Recently I got involved with it because of the cryptocurrency industry. If I want to say a number, I can say 30 percent.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

In my opinion, the most important issue is the challenge that we are already dealing with, and it is transferring money. It can accelerate the process of transferring. It can bypass the role of middlemen and decrease the time and consequently the cost of the project.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

Again, the problem of money transfer is the biggest problem and challenge. What is very important for us right now, is money transfer. I even pointed out the use of this technology in one of the meetings we had with the board of directors, but as I am going to mention in next questions, there are problems with the implementation of this technology in our industry.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

Since this is new, the biggest weakness is the unfamiliarity of our partners with this technology. For example, in the last meeting with Secheron, a Swiss company in the heart of Europe, we realized that there is not enough knowledge in this field. When I introduced blockchain and its features to them for the first time on my trip to Switzerland, I realized that there was no knowledge of blockchain and digital currency, and they did not know that money transfer could be done with a few simple clicks. It was Switzerland that lacked knowledge in this field, it goes without saying that Iran lags behind Europe in implementing new technologies. When we even talk about transferring money through blockchain, it seems scary and vague to them.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

Old processes and structures which have been shaped in a traditional manner over the years. Unfamiliarity of those people who are involved in this industry and their resistance to the changes.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

Specifically, for blockchain, I have not come across such regulations. But, in financial transactions and digital currencies, since my focus is on money transfer, there are limitations to money transfer through blockchain. For example, I know that there are preventive regulations in China, as well as in some states of the USA and Canada. In particular, there is a legal gap in Iran, and we do not have relevant legal regulations and restrictions. I say it is not forbidden, although it is not legally approved. But there is always the risk of being outlawed.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

The biggest is to teach them not to be afraid. Second, we can introduce them to Blockchain's benefits. Third, we need to convince them that blockchain does not compromise your benefits. As you know, in some cases, commissions are paid to intermediaries who carry out contracts or facilitate transactions. If blockchain threatens the benefits of these groups, they will resist it. At least initially we have to convince them

that their benefits will remain unchanged. The first group that loses in these systems are the middlemen. Of course, we shouldn't call it corruption many times, but these are the services of companies that can bypass sanctions. Some of these companies will lose their advantage if we are in direct contact with suppliers through blockchain.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

5- JB 24.05.2023 12:40 PM

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects.

I'm a project manager and I'm already working on the Isfahan project. Due to the need to deliver goods for my projects, I place orders with various purchasing companies. At different periods of time I request specific equipment, services and technical services in order to proceed with the project I manage. I announce these needs in coordination with the planning and project control department.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

The first is sanctions and because of the sanctions, a restriction on the suppliers who work with us. Timing of the supply, which we cannot exactly schedule and count on. The theme that says whether we are buying specifically what we need and whether what we are buying meets the needs of the project. our technical and engineering knowledge is not so advanced that we have different choices for sourcing our needs. We are currently buying based on our suppliers. So, we are technologically restricted by the suppliers. The money transfer or better the financial schedule is too problematic. There is a risk that after entering into a contract we may or may not receive the goods and services and also after sales services.

1.3- How do these challenges impact the overall success of railway construction projects?

These problems and challenges increase the risk of project failure. This also increases the time we need to complete the project. Our dependence on Verndors means that we are unable to manage the costs and expenses of the project. We enter into a contract and buy a product whose supplier increases its price, and we have to pay extra for it. There is no other way. If I want to name the most important ones, is the management of time as well as management of costs.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

We had a supplier who was supposed to supply the batteries for us, but during the project period, due to the increased dollar price and the risks involved, he doubled the price of the goods to cover the risk of inflation. So, what we are expecting is costing us A rials, costs us 2 A rials and there is nothing we can do about it. Since we had to buy this system, we had to pay twice the cost and in practice we fail to manage costs.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I've only heard about blockchain from a supply chain perspective and also read the slide you sent and looked it up a bit on the internet. I understood the concept and its characteristics, but I don't know anything about the existing infrastructures and the steps we need to implement it and how we can develop it. Whether each country can

develop it by itself or whether each industry can develop it by itself I don't know. I think it's like a new business concept for us.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

It may cause some consequences in our country as well as in our business. One is that it can prevent corruption. The corruption we do not like, but we have to get along with it. For example, imagine that we have 5 suppliers, and we have to deliver our goods only from them. This leads to corruption. Another problem is the speed of the cost estimation. For example, if we need to bid on a tender, or for some reason we want a cost estimate for our project, we can use this technology to do a general cost estimate. Another benefit is knowledge management. For example, you perceive that there are some contracts in this chain, and I can see through the draft of those contracts and we can make predictions for our project and see the lessons we've learned from others. Another problem is that blockchain offers the possibility that all suppliers who want to work and deliver, but do not have data on whether there is a customer for them or not, can enter this chain and reap the benefits. This not only means advantages for buyers, but suppliers can also present themselves within this infrastructure. Certainly, this technology increases competition between vendors. There is certainly room for not enough well-known providers who are new to the market. These vendors are willing to work with higher quality and lower price than other renown vendors. In general, this could be an infrastructure for approval of validation of vendors.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

Existing infrastructures are not enough. For example, in our country it is not economy wise common to have real data from other companies. And companies do not share their financial data. The concept of monopoly law in our country has not attracted so much attention. It is probable that exclusive or single vendors that exist in the market, does not enter this chain and force the customers to buy the goods out of Blockchain system. Whether through the rent and privileges they have or the power of their acceptability. And there is no anti-monopoly law to stop them. It also requires a safe and strong communicational infrastructure. I do not know whether this matter has any special proctor or not. If there are companies which create this infrastructure or not. Another concern is that the companies which create this infrastructure are state companies themselves and there is always the risk of corruption. Because when you do not trust a state company, then you cannot trust the companies which provide them with the infrastructures. Another issue which could be problematic is that state economy implies corruption and any movement towards transparency causes a lot of resistance.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

If want to list the titles, one is that state economy does not allow transparency in processes. It means state economy is against transparency which is required in free market. Another issue is that state projects which are countless., pursue other goals than projects in free market. A free-market project’s goal is to do the project with highest quality,

cheapest price, highest satisfaction of client and highest profit, but a state projects does not pursue these goals.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

In our industry, all regulations seem to aim at transparency. The laws and regulations that are set to eradicate the probability of corruption taking place. For example, tendering regulation which tend to make all the things follow the rules and reduce human interference. For example, one of our main stakeholders in many fields in our industry are military related companies. These organizations are whether influential clients, influential customers or influential stakeholders for which sharing knowledge and transparency in data compromises their benefits. Also, there is a culture in our country and that is describing a situation in which a new things fail to be implemented and developed. Then, it brings resistance against all the similar things that is going to happen.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

The most important requirement is building the infrastructure and try to build an accepted culture. We should not take very big steps which are very comprehensive. Instead, we need to develop some small basic steps. We should first build the infrastructure in some small industries which can be benefited significantly and expand in these areas to show the biggest industries the benefits of Blockchain and the low risk of implementing it. When these bigger industries start using it, it will expand in the whole market. I believe one solution could be stablishing start-ups based on this technology and selling them to bigger companies.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?
In my opinion, the biggest feature of Blockchain is the user's confidence in its structure. First, the stakeholders need to ensure that the data they provide is based on a secure infrastructure or not. Ensuring that the data is not shared simply with anyone, gives the data provider a better chance of deciding which category to put the data into. For example, some data can be shared by all users, while others should be shared by premium users or only a limited list of partners. Or when I want to share it on an open platform, there would be the possibility to share it anonymously. This trust in network structure is really important and very controversial in our country because there are some users that have access to lots of confidential information. Another point is the trust of stakeholders to each other. Whether they think that the data is sharing will be misused by others or not. If they trust each other, then they may share the data without having big concerns.

6- AM 24.05.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I'm a procurement engineer. I buy electrical equipment for railway projects mainly in cities.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

In my experience, the number of suppliers of some devices is problematic. For example, when it comes to third rails or DC switchgear, we only have a few suppliers who meet our requirements.

1.3- How do these challenges impact the overall success of railway construction projects?

There are impacts on three main pillars of the projects. time, price and quality. This increases the price, increases the delivery time and therefore the execution time, and manipulates the quality. Restrictions due to sanctions, restrictions on money transfers, limitations on the number of suppliers mean that you cannot have more leeway.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

For us, for example, the suppliers of busbars or third-party busbars or DC switchgear are limited. These providers are also very limited on an international level. Therefore, we cannot have multiple options and must get along with the existing suppliers and move on. We had such problems in Tehran Metro Line 3 Project as well as Isfahan Metro Line 2.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I have a superficial and brief acquaintance. I know the definition and some properties, but haven't studied them thoroughly.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

I believe it could be helpful through smart contracts. The advantage of smart contracts can be that they reduce the role of the contractual guarantees that the partners have to give each other. You shorten the time for contract negotiations. Partners can more easily achieve a common goal. Generic blockchain features like transparency and decentralization can also be helpful. By interfering with and minimizing the role of banks, intermediaries and middlemen, both sides of the negotiations can benefit.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

It causes the project management to become agile. This technology can improve our decision support system. The output of this technology can be used in a decision support system.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

I can't recall any downside particularly related to the railway industry. I think if there are downsides, there will be similar problems across the industry.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

Hardware and software infrastructure may be required. I don't know exactly what infrastructure and foundations we need, but there are certainly some and if we want to implement Blockchain in the railway industry.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

Since this is a new concept and has not been implemented vastly so far, I think there is not any regulatory or legal hurdle for that, but future wise we will certainly face some prohibitive laws and regulations.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

education and culture building. We need to show stakeholders how it works and how it will be implement in industry and in everyday processes. We need to acquaint them with the ins and outs of this technology.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

In the railway industry, which is not culturally advanced, there are of course concerns. The companies are afraid to share their data, but I don't know exactly what to do about it.

7- JS 26.05.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I work in 2 areas. One is the strategic planning for an organization operating in this industry, and the second is business development issue. In the first part, as we were writing the strategies, we looked at the organization's existing value chain to see which areas of business we could enter. For example, a metro project consists of three fields. Construction, equipment, and fleet. We had written a strategy for this so that we could also get into the construction part. And if we as marketing and sales managers now want to enter a new value chain, we should assess the following: If we want to implement a new value chain, we must see what value this chain has for us and what hurdles the new field brings with it.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

Subject to sanctions that prevent us from reaching out to suppliers and payment to suppliers against the goods and services we receive. Financial condition of the employer that makes it difficult when we must pay for our projects. Also, price increase. The prices change regularly. In many cases, the rules and regulations change. For example, at the moment we have a rule which requires the companies to use domestic potentials and domestic suppliers. As a result, although we have competent suppliers throughout the world who are willing to work with us, but we must make a contract with domestic suppliers in order to support them. Also, corruption and bribery in the industry leads the competition not to be fair.

1.3- How do these challenges impact the overall success of railway construction projects?

Impacts on three main pillars of the projects which are time, price and quality. This increases the price, increases the delivery time and therefore the execution time, and decreases the quality. Restrictions due to sanctions, restrictions on money transfers, limitations on the number of suppliers mean that you cannot have more leeway.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

As an example of the signal system, which is a critical system and has to do with security, I would like to explain how the quality is reduced. In this regard, we have a domestic manufacturer who has conducted research and development. However, its system does not meet international standards and its quality is not comparable to international competition. However, since the price is cheaper, and a domestic company should get support from the industry, we need to make a contract with them. If there is any delay or quality drop, we can't complain because there is a monopoly in the market.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am theoretically familiar with Blockchain. I have a research paper in this area. I have also attended some workshops and trainings in this area. These training courses are carried out by the MAPNA Group for all subsidiaries. The aim is for different areas within the group to familiarize themselves with blockchain and propose their idea if they have an idea to implement this technology.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

If I want to talk more operationally, let's go back to the three project factors: cost, time and quality. One thing that takes place in Iran is inflation and price changes. A few times after we sign a contract with a company, the supplier company claims that my costs have increased due to inflation. For example, our supplier says when we signed the contract the dollar was 3000 and now it's 6000 and the raw materials, I want to buy are getting more and more expensive. Therefore, we must agree to an increased price. This claim may not be true. It could be that the supplier had previously bought the raw materials and now only wants to abuse this inflation and make profit from this vague atmosphere. But if this process is defined on the blockchain platform, everything is traceable. When did we make the down payment, when did the supplier buy the raw materials and what was the price of the raw materials then and now and so on. As a result, the price becomes under control. In terms of timing, currently we can only request a production milestone before delivery, or at most inspect the production line regularly during manufacture, which is not enough. If I would like to describe it with an example: We once had a problem with one of the suppliers who had promised us to prepare 45 km of cable in a certain time. But he couldn't, and that could damage our image at the political level. But with blockchain, we can improve that timing with real-time tracing. And about the quality, for example, we have a contract, and the supplier outsources the goods to a Chinese company that makes a lower quality product. But in a smart contract and within the blocks, we can track each moment and see if it produces the good itself or outsources it.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

Transparency, traceability, and security can the major impacts on supply chain

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

One caveat is that the railway industry in Iran is not an agile industry. For example, a project should be completed in 18 months, but in practice it takes 7 years and delays are not to be feared. Additionally, the industry needs maturity for blockchain to be implemented. There are different technological maturity levels of different companies. Some use new technologies, while there are companies that hardly use a computer. This makes it difficult to bring all these companies together on one platform. Also, we lack facilities related to the supply chain itself, let alone the use of blockchain in the supply chain. Some industries in Iran, such as the automotive industry, are very advanced in supply chain issues, but the railway sector is not mature enough. Another disadvantage is that blockchain is difficult and complicated. We are subject to investment restrictions and regulatory restrictions. Also, we have a weak electronic

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

Hardware-wise, part of the blockchain implementation in the industry is based on the Internet of Things. The basis of the IOT is now the internet itself. And we have internet restrictions in our country. This means that our internet facilities have not been increased due to political and security restrictions. Internet speed is low. We don't have 5G internet. Therefore, we cannot collect the data online. If we want to invest in facilities, we don't have the money, on the other hand we have little expertise in this area.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

I do not know any regulation which is challenging, although I do not know any regulation which encourages using Blockchain.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

These kind of topics needs encourage and punishment at the same time. We have techno-push and market-pull. Regarding Blockchain, we do not have any market-pull. Because the market is not familiar with it. If we introduce Blockchain and train the companies, this need could be created. But, in my idea, a big part of it should be techno-push. For example, a company like MAPNA can set a regulation for its supplier to work in Blockchain platform. We can push this technology because we have a large market share. If we do not force our suppliers to use this technology, there would not shape any Blockchain. Since the whole chain should cooperate in this platform, the one who is the biggest leader in this chain can push other companies towards using it.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

Our company is an EPC contractor and 85% of a project value comes from supplying materials, goods, and services. As a result, a great part of our profit is in purchasing. And how we can buy these goods and services and how we can charge the client is one of our competitive advantages. If we enter a chain in which we share these data, it downsizes this advantage. Inside the chain, this data sharing could be not a big deal, but when this information will be shared outside the chain, it could jeopardize our competitive advantage.

8- FH 26.04.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

My position is Head of Engineering in the field of metro and electrical railways. I and my team certainly play a role in ordering project requirements to the procurement department as well as in the initial equipment assessment and definition of technical specifications. Daher prüfe und studiere ich die vom Lieferanten erhaltenen technischen Unterlagen und Zertifikate.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

Providing the budget is the biggest challenge. We have to pay a deposit and also pay our suppliers during the manufacturing process. The procurement of raw materials is problematic for manufacturers due to the sanctions. Quality of packaging, transport (in route and at destination) and unloading. Also, the quality of the final product that we receive is one of our challenges.

1.3- How do these challenges impact the overall success of railway construction projects?

Delays in the delivery of the goods, poor quality, improper transport and storage can adversely affect the projects and in this way lead to client dissatisfaction.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

That is certainly the case. As I mentioned in the first question, we have financial problems. The customer cannot pay us and consequently we cannot pay our suppliers, causing project delays in some of our projects such as Tehran Metro Line 6. Sometimes there is a lack of electricity or gas for our suppliers and hence our projects are delayed, as we experienced with Tehran Metro Line 6 and Isfahan Metro Line 1.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

The truth is that I know the concept and functions of blockchain to a certain extent, but in our country the infrastructure is not prepared and not yet significantly implemented in organizations and companies. So, I don't have complete information about it. This cycle has not yet been implemented and tested. So, I don't know anything about the implementation of this process.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

Certainly, it can act like a database; This technology can act like an automation system; It can mechanize a process and therefore this technology can play a crucial role in shortening the distance between production and delivery. It can increase contract signing speed. Transparency between and partners. Also assess and rate the companies you work with as a supplier. Then a transparency facility that can link our industrial circuit to the international circuit, giving us the opportunity to expand our business and export our products to other countries.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

One aspect we always use to judge our suppliers is their ability to source the best raw materials. For some products we require an international certificate from an international laboratory, and it is important for us to track our suppliers to ensure they always source their materials from verified and high quality suppliers.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

One of the concerns is that our data will be misused by competitors, our customers, or our clients etc.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

Any technology that wants to come to market needs a set of facilities and infrastructure, and the government must provide these facilities. We need an assessment system. Several standards need to be defined. All services and devices must reach an acceptable level such as different ISOs. We also need a superintendent to review the data shared by partners on the blockchain.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

It definitely is. For example, the internet speed limit according to the regulations. There are also regulations within companies that oblige companies and organizations not to pass on their data. These regulations mean that the speed of implementation is restricted.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

The advantages of this technology should be defined in a way that introduces this technic as a reliable and beneficial approach. In this way, the partners can trust in. This trust is built if the partners make sure that through this technology, they can reach faster to target market and reach to larger markets. It can be explained that official bureaucracy will be reduced by implementing this technology. The paperwork is reduced. Transparency will increase. They should make sure about all these.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

In terms of new technologies, there would be always concerns. Even regarding some searching engines or communicational application like Google, there are still concerns. But the solution is setting laws and regulation in this regard. Laws in order to punish those who cause leakage in information. For people who implement this system should exist a system who always support them and they can refer to when there are legal problems or misuse.

9- AG 26.04.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I work in the technical department as a technical expert. If the procurement or purchasing department needs technical information, I am responsible for it. Or if there is a technical question or problem on the part of the supplier, I meet those needs. If our company wants to buy something, I will prepare some technical requirements and documents. According to this technical file, the commercial department conducts a tender or requests an offer. Then when these technical offers come, I read and evaluate them.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

If I want to say that there is a priority, the first is the sanctions. Iran is a country subject to sanctions. It's difficult to get the materials. For this reason, we source some goods from internal suppliers, but for some goods we do not have internal substitutes and are forced to import from abroad. In these cases, the relationship and communication with the manufacturers is the biggest challenge. We need to build these relationships through some middle companies or some layers. Therefore, our technical questions and technical concerns about the supplied equipment need to pass through these layers to reach the main manufacturer. Because when we ask our questions and technical problems directly, they don't answer us. As a result, the price and time of the project will increase. Sometimes the price, increases up to 60% of the main price. The second Challenge is convincing the client's consultant when we want to bring a new vendor in our vendor list. We should argue a lot in this regard. Another issue is guarantee and some factory tests which we have with abroad suppliers. Although there are some domestic companies that gives us services relating these goods, but the quality of services is not high and we cannot rely on.

1.3- How do these challenges impact the overall success of railway construction projects?

These challenges and problems cause many difficulties in our projects. The completion of the project will be affected. This means that we cannot meet the deadline. The projects remain open, and the customer does not complete the project because, for example, you cannot supply a spare part for a system and the project is not completed in practice. Another issue is the quality. The client can say that because of supplying goods from a domestic company, the quality is reduced, and I cannot take on the project. I believe the time and the quality are the main consequences.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

For example, in one of our projects, we bought the clock system from a domestic manufacturer and encountered many soft and hard defects. As a result of these defects, we cannot charge the client appropriately and our profit has been decreased. When it comes to project hand-over the client does not accept these defects and we cannot finish the project and therefore we loss. As an example, we made a contract with Honeywell and at the end, they did not provide us with a

license instead of a dongle. It caused us not to complete the project. We made the contract with this company because in an international level, we do not have bargaining power.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

Because of cryptocurrency, I became familiar when it came to the market at first. I studied a bit and found out other features of the blockchain which I find very useful. I think the world accelerating using it throughout industries.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

In each field that we work, we can distinguish some good suppliers and get connected to them. Communicate our needs with each other and create a fruitful interaction. Then, each producer turns into a Block. A block that I can reach in order to meet my technical, financial, and contractual needs in a transparent way. In the next project, I can use these records. I can either enter to relationship with the same partner or omit it and find another vendor. In this way, you can create a chain of companies which are all qualified and as time goes on, you can store more information and expand the chain. For example, we have a supplier for our FAS system, and we had some contracts with them. So, we have a lot of technical and contractual record of cooperation, and it makes it easier to communicate with them for our next projects either in corporation level or between persons. It is not like a new company which so many things are vague about it. In a professional level, if we want to avoid long-term negotiations and many meetings, we can make smart contracts and simplify these processes. Everything could be brief and reliable inside Blockchain.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

If we look at it ideally, we can build a very big chain where our company together with other partners can transparently share the data and there are no companies abusing the data. It means some companies lose their exclusive advantage by becoming part of this chain. There are certainly pros and cons. On the one hand, a company can find partners and make contracts easier. On the other hand, some companies are no longer limited to making very high profits. Ideally, the transparency is so high that the projects can be completed very easily and the time for project delivery is drastically reduced. It is very ideal, and I think in Iran is not applicable.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

The downside is that the nodes of this network should trust each other and trust the network. There is no central supervisory authority that confirms the processes taking place in this chain. In countries like Iran which there is lack of clarity in, it could be a big drawback. You can begin a process and invest a lot and go ahead, but because of this lack, you end up having a big failure.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

As an example, one of the hurdles that exist is the monopoly of some companies. The client limits the network to some specific vendors and a new vendor should commit corruption to become part of the approved vendors. These things take place in a big scale in our country. For example, the client's consultant provides the technical document in a way that their preferred supplier wins. That means a series of companies have dominated the industry and the governmental clients and their consultant are in this team who commit corruption.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

Based on some politic and security reasons, there are some rules that explicitly prevent us using systems and equipment which are internationally renowned but are made in countries with them we are in cold war and there is a fear using their equipment in sensitive parts of railway industry. Political and security reasons is preferrable to technical quality.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

We need to stablish a case in a small scale and the benefits becomes clear. Also building cultures and educate the companies.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

If we want to look from a business perspective, everything should be shared clearly and transparently. I believe the know-how that bring about competitive advantage, should not be easily shared. If the partners want to share and access such data, they need to enter an agreement. It can be that the holders of this knowledge who are pioneers in the industry charge other partners for this valuable knowledge which is rational in my point of view.

10- JS 27.04.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I am the Head of Electrical Equipment Engineering at Behro Engineering Consulting Company. We read technical documents. If there are any contradictions or deviations from our requirements and standards, the contractor is obliged to clarify these until we have finally approved and released these documents. Also, after the contractor conducts a tender among its suppliers, it sends technical documents of its suppliers for review and approval of these documents. After the manufacturer or supplier has produced the goods, we are invited to the Factory Acceptance Test. Then we request spare parts, specific goods and warranties, etc.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

There are two main challenges: Prices and timing. On the one hand, the client, the Tehran metro company, is facing serious financial problems. On the other hand, Contractors could also be guilty themselves. It may be that the deposit is paid, but the contractors are not able to manage this budget. Sometimes some systems could be purchased at the end of the projects, while the contractor purchases them at the beginning. For example, SCADA System is not a system which is needed to be bought soon but, there are other system which are more essential to be purchased first. The contractor should manage these things. Another challenge is timing. A timetable and priority of execution will be given to the contractors initially, but this timetable is subject to change. The relationship between employer and employee should be designed in such a way that they can cope with these time changes together. Also, the contractor might not have a strong engineering or execution team. But timing and budget management are two of the most important aspects.

1.3- How do these challenges impact the overall success of railway construction projects?

In practice, money is a very important factor. Until our contractors receive their money, they cannot contact their suppliers. When our contractors want to execute a line, they need to provide some packages like signaling, power supply, cabling etc. together.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

If no money is not made available and there is inflation, goods usually become more expensive. It could be problematic for Client as well as contractor. We had examples where, for example, the construction was already prepared, but the electrification was not yet fully completed. Therefore, the project could not be approved. Therefore, all the workers missed the time.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

With this name, I am not familiar with, but I studied about some features of this technology. But I have not had any experience about this technology.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

It can ensure the client about the quality of the good that it buys. The client cannot regularly inspect the goods in production line. There could be a platform on which our contractors stay in contact with some big suppliers and row material providers. It could lead to quality improvement.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

For example, in connection with the manufacture of cables, which is a very important asset in any project and where no project can be carried out without cables, the raw materials that make up the cables can be traced. The use of blockchain makes it clear from the start how the manufacturing process works. Which companies has produced the materials and the cables and in what quality also become clear.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

I believe that there are no disadvantages. However, one limitation could be that the manufacturers do not want to pass on their data. There is technical knowledge that manufacturers or contractors haben and for some reasons do not want to share it in a platform.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

First of all, all manufacturers and generally all partners must agree that blockchain is a necessity for the projects. Probably not all partners are familiar with blockchain. The benefits for stakeholders must also be presented. Then stakeholders can handle their processes on such platforms more simply and easily. Through this platform, partners can establish a direct relationship with the companies that produce raw materials or provide other services. For example, we once found out that the weight of a transformer is higher than the technical requirements. After much investigation, it became clear that it was a matter of changing the transformer oil. If we could trace all commodity producers within a chain, we could find the reason easier and faster.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

In Railway industry, I do not know such regulations.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

As I said earlier, we should first describe that using such a chain is a great advantage for themselves. For example, a contractor provides one of our projects with a control cabinet that consists of so many components. If an error occurs in this cabin, the contractor can determine the

cause of the problem himself by tracing back the components and producers within the chain. The component causing such problems can be detected.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

> Data protection applies in particular to military concepts. But manufacturers also want their data to only pass through that chain and not be passed off-chain to competitors or companies who misuse that data.

11- NK-online 11.06.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

Logistics Specialist

1.2- What are the biggest challenges in the supply chain of railway construction projects?

- Manufacturing delays: they may change the shipping date due to quality issues or their potential shortages
- Port congestion and delays in unloading the cargo
- Shortages of critical basic materials & consequently their rising prices
- Ongoing regulation changes to release products at customs

1.3- How do these challenges impact the overall success of railway construction projects?

- All the delays in the manufacturing phase or shipment lead to delays in delivering the projects on the promised time
- To mitigate the risk of delayed projects, we will have to incur increased costs especially in their logistics and customs clearance phase

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

Yes, there were times when there was a new regulation issued for the product we were expecting to receive at customs.

Although all required documents to release the product were prepared, we had to go into a new process due to the new released regulation. This could include extra lab and testing phases to make sure the national standards are met. This long lasting testing process kept us behind the project and made us pay more than expected for the testing costs.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am familiar with blockchain to some extent.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

- Blockchain technology can provide real-time visibility and tracking of goods and products throughout the entire supply chain, from production to distribution to end consumers. This helps to increase transparency and trust between different parties in the supply chain.
- Blockchain can be used to track the quality of products as they move through the supply chain, enabling faster identification and removal of defective products, reducing waste and improving customer satisfaction.
- Inventory management: using Blockchain, all parties such as warehouses, manufacturers, suppliers, and distribution centers connect to each other sharing the records that are accessible to everyone within the network. Blockchain can be used to track inventory levels and optimize inventory management processes, reducing bottlenecks, inventory costs and improving supply chain efficiency.
- Having access to transparent records of supply chain processes, Blockchain can reduce the risk of non-compliance and related penalties.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

Blockchain can reduce the delays, extra costs and human error. It can also reduce the number of dealers involved in a supply chain process resulting in less fraud. Since records are not able to be easily erased or edited, using blockchain brings more transparency and trust into the whole supply chain process.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

Yes, data immutability can also be disadvantageous as there is no way to correct inaccurate data on a blockchain.
Also there is a threat of 51% attack in which data cannot be trusted.
Another limitation can be when a blockchain cannot be integrated with an existing ERP system, since they may not support the blockchain technology.
We also need to see if all our vendors, and supply chain parties would like to join a blockchain. They may not be necessarily willing to do so for whatever reason like data security, and so on.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

- It takes time for organizations to see how blockchain can help them with more efficiency and how it is better from other existing cheaper technologies.
- It also requires training and educating staff on how to use this technology.
- It is an expensive tech to implement, with high energy consumption.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

- I think the main legal challenge and concern is to realize what jurisdiction is applicable when it comes to resolving disputes, because blockchain technology is global. For example, if a smart contract is hacked and funds are stolen, it is unclear who is liable for the loss.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

- Stakeholders need to be told about how blockchain works and all its benefits.
- They need to know what specific problem(s) is going to be solved using blockchain and how the success made can be tracked or measured.
- Since it is a big change, they can be told that there is no need to shift the whole supply chain platform to a blockchain. We can start with a single feature used for tracking delivery. Once the results are visible to stakeholders, they may decide to expand using other blockchain features.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

- The Main concern coming to my mind is the 51% Attack. Having a powerful cyber security team, railway companies can prevent this vulnerability.

12- MR E-Mail 14.06.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

My role in the supply chain in this project is to prepare the schedule and control the schedule of contractors and subway equipment manufacturers, as well as provide a status report on the progress of the supply of equipment, provide a schedule and control deviations from the schedule, and provide compensation plans to fulfill the schedule desired by the client.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

In my opinion, the biggest challenges in the supply chain in our country are as below:

- Sanctions

- Lack of financial resources and indiscriminate and unplanned injection of financial resources

- Compulsion to use domestic producers and limitation in choosing the seller and capacity limitation of domestic producers.

- Restrictions on money transfers

1.3- How do these challenges impact the overall success of railway construction projects?

In my opinion, these challenges have at least an impact on the following:

- Reducing the quality of the final product

- Creating a delay in the schedule considered by the clients

- Increase in the cost of the project (due to the increase in time and the lack of competition in the supply of equipment)

- Increasing the workload of personnel and the need to update the scheduling and control programs several times

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

In my opinion, these challenges have at least an impact on the following:

- Due to the sanctions, it was not possible to supply DC equipment from Secheron and this led to an increase in cost and time delay in the project.

- Due to the delay and unplanned payment of financial resources, it was not possible to plan in advance in the supply of project equipment, and due to the increase in the price of currency in the country, it led to an increase in the total cost of the project.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am somewhat familiar with blockchain, mostly through cryptocurrencies

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

The fact is that I did not have work experience in this field until now, but according to my work experience and the brief acquaintance I had with blockchain, I think that blockchain can be useful in the following areas:

- Blockchain's ability to decentralize and verifying information in the supply chain can be helpful.

- Financial transfers can be made through blockchain

- Blockchain can be useful in creating unique identifiers for goods and help contractors in purchasing genuine goods and avoiding fake goods.

- The transfer of confidential information can be done on the blockchain platform

- The processes related to holding tenders can be done on the platform of blockchain and create good confidence for the contractors participating in the tender.

- Money transfer can be done more easily on the platform of blockchain, especially for less developed countries that have fewer facilities to accelerate money transfer and reduce the monopoly of strong money.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

For example, in my opinion, blockchain can reduce the time-consuming process of customs clearance, and by creating unique encryptions on the goods entering the customs, the information of the cargoes imported and exported from the customs will be easier to control, and it can be an effective help in preventing the smuggling of goods in Customs and under-declarations or defective declarations

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

As I said, I didn't have the experience of using blockchain in the railway industry, and I haven't heard that blockchain has been used in the railway industry. But it is obvious that the

use of any new method in a process (especially in the supply chain) can have advantages or disadvantages that should be commented on after examining all aspects and repeated tests.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

The topic of blockchain is a complex concept and its implementation requires a complete and correct explanation among the members who use it in organizations, and I think its implementation requires the creation of an easy-to-use software platform.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

Probably yes, because in most countries no rules have been defined for the use of blockchain, and also many companies may refuse to provide their information in blockchain format through some regulations, and join it due to lack of familiarity and avoiding unknown risks.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

- Introduction of blockchain in the set of stakeholders

- Full explanation of blockchain in the group of stakeholders

- Providing practical examples to introduce the advantages of using blockchain

- Creating suitable infrastructure and facilitating its use

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

13- MF Online 11.06.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

As the Head of Equipment Supply, 0 to 100 equipment supply process from announcing the needs of the projects to identifying the approved vendors, preparing the short list, preparing and completing the tender documents and sending them to the suppliers, receiving proposals, preparing evaluation reports, price estimation, the selection of the winner and the conclusion of the contract will be initiated by me. Things like coordination of transport, insurance, custom clearance and transfer of the goods to the warehouse can also be done through me directly or with the help of a logistics expert.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

In the company's current projects, the main problems in terms of supplying equipment and services are: 1- Severe restrictions in choosing foreign suppliers due to sanctions 2- Exchange rate fluctuations, high inflation and constant and daily price changes that cause Many claims are made by contractors 3- Failure to provide necessary liquidity by clients and as a result delay in payments and consequently delay in receiving equipment 4- Time delays caused by reasons beyond the control of the company such as project site not being ready.

1.3- How do these challenges impact the overall success of railway construction projects?

The existence of the above challenges and problems causes additional costs as well as unavoidable delays in the implementation and completion of projects. Although the project is finally completed, but with a long delay and the cost is several times higher than the initial estimate

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

For example, in the telecommunication equipment supply (radio system), due to the drastic changes in the exchange rate, as well as the delay in the payment and completion of the advance payment, the contractor did not succeed in placing the order on time, and the main manufacturer did not succeed in placing the order due to the inflation in his country increased the prices. Also, the prices of domestic equipment and services were adjusted due to inflation and salary increases.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

Blockchain is a digital ledger of transactions that are copied and distributed across a network of participating nodes. This technology can track transactions from beginning to end without the need to consult a central authority responsible for maintaining the transaction or encrypting data and without the need for human intervention.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

The advantages of this technology in improving the supply process are: 1- Creating transparency in the information related to the supply chain 2- Existence of decentralized structures 3- Preventing the entry of middlemen and reducing the cost of supplying equipment 4- Information security and creating reliable access for all parties Involved in the project 5- Complex encryption and the impossibility of information theft 6- Simplifying the supply process through smart contracts

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

In the area of contracts, from the conclusion to the implementation of the terms of the contract, blockchain can be very helpful by simplifying and speeding up the processes. Smart contracts are contracts in which without the presence of third parties, if the conditions in the agreement are met, payments or other contractual obligations are automatically realized.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

The current limitations of using this technology are mostly due to the lack of infrastructure, necessary knowledge, lack of awareness of company managers about the benefits of this technology, which seems to be resolved with the passage of time and the provision of the above fields.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

One of the main obstacles to the implementation of blockchain in supply processes can be groups that see their interests at risk with the spread of this technology, for example intermediaries. or companies whose current business activity is based on cryptography, coding and similar tasks.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

The entry of this technology into the field of commercial exchanges and its globalization requires the approval of the governing laws and the removal of obstacles and prohibitions that currently prevail in parts of these processes (including the issue of cryptocurrencies).

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

Introducing blockchain technology as fully as possible, holding training courses for experts and managers involved in the field of equipment supply, and also getting help from government institutions in order to ensure effectiveness, speed up and create security in related processes can be helpful.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

Considering that the blockchain stores data using complex software and mathematical rules, it is almost impossible for attackers to manipulate the information. This means that there is a unique type of encrypted digital fingerprint that It is safe and very reliable against manipulation.

14- KM 29.05.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I am the project manager, and I am currently leading the 6 metro line project. My work starts from project planning, then requests for supply of goods and services, supervision of project implementation by experts as well as contractors and subcontractors, project testing and delivery to the main customer, which is Tehran Metro Company.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

Considering the economic and political conditions of our country, our industry is facing many challenges. The main challenges related to the supply chain based on their importance are unfavorable financial conditions and unpredictability of financing timing, finding reliable and high-quality international companies to work with us when our industry is under sanctions, finding reliable domestic suppliers who are able to meet the project requirements, and corruption.

1.3- How do these challenges impact the overall success of railway construction projects?

Delays in payment and lack of sufficient funds cause long delays in projects and damage our image in the eyes of vendors who are now working with us. Failure to cooperate with high-quality companies and failure to provide high-quality equipment and services leads to a decrease in the final quality of projects. This poor quality itself can cause a delay in delivery because the main client does not want to take over the project due to low quality. In case of such problems, the cost of the project will increase, and increased costs, long-term delays and reduced quality can lead to not achieving the goals and will definitely affect our brand image.

1.4- Can you provide examples when these challenges have led to project delays or cost overruns?

Such problems can be found in any project in our industry. For example, in line 6 of Tehran metro, there are systems such as clocks or closed-circuit cameras, which were not accepted by customers. This means lower quality and more costs and delays in the project.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am not fully familiar with all the features, but I know that it provides a platform that can be very useful in the supply chain process. I have read articles and searched the internet as well. As this system is not implemented in systems that I am familiar with, I do not know how it works in practice.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?
First of all through transparency. Transparency helps a system to be agile. All stakeholders can see what is going on in the project and when a problem is happened, they

can manage the problem in time. Secondly, Traceability enables buyers and other stakeholders such as contractors and customers to ensure the authenticity of goods, raw materials and downstream producers. Thirdly, Smart contracts help by speeding up interactions and financial transactions. Finally, Immutability allows all stakeholders to be sure that the data is untampered and reliable.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

Interaction between stakeholders becomes easier and facilitated. There will be real-time monitoring of processes such as production, shipping, delivery and payment. It also provides a platform for a competitive marketplace by sharing data and giving all stakeholders, such as new vendors, the same tools for doing business. As mentioned earlier, it can be a platform for agile management. Also, with transparency it provides, corruption does not take place or is limited.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

As drawback, I can mention the costly process of implementing blockchain. Also, taking some competitive advantages of some companies and sharing them with all stakeholders which could demotivate companies from being innovative. As limitation, I can mention lack of international platform, not familiarity of all players in supply chain, some influences which come from corrupted authorities,

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

I believe the biggest barrier is lack of proper infrastructure. Some partners are technologically savvy while others are unfamiliar with the basic concepts of new technology. This technology is very complex and requires a strong research and development unit to develop it. The costs of implementing this technology for some companies are very high compared to the income they have, and it does not make sense for them to invest in this technology. Another obstacle can be the resistance of some companies that play the role of intermediaries in the current system or are even corrupt and feel scared when new technology comes. As another obstacle, I can name the lack of comprehensive and integrated laws, regulations and standards among different businesses and different countries.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

I haven't heard of any legislative or regulatory barriers specifically against this technology, but I also haven't heard of any encouraging or facilitating regulations. But some public regulations such as the "Domestic Product Protection Law" can act against the creation of an international and free platform to join based on blockchain technology.3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology?

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

Of course. There are always concerns when it comes to data sharing. I am not aware of all the aspects and concerns. But when it comes to sharing data, which can be a company's competitive advantage and should remain in the chain, some stakeholders have concerns. I think we can deal with it by passing strong laws and agreements. Also, companies can grade data and share data that is no longer confidential. Maybe they can choose which data to share with which partner, but I'm not sure if that's technically possible.

15- MY 02.08.2023

1. Finding out the problems and challenges in supply chain of railway construction projects:

1.1- Please describe your role in the supply chain of railway construction projects

I was part of the engineering team working for an EPC contractor. We were involved in some subway projects in Iran. In the electrical department, we were supporting engineering and also the execution phase of the projects.

1.2- What are the biggest challenges in the supply chain of railway construction projects?

As you should know, the big challenge is sanctions and limitations related to sanctions. The root cause for all challenges are sanctions and political issues. Other issues are somehow related to these sanctions.

1.3- How do these challenges impact the overall success of railway construction projects?

As you may know, each project has three criteria. Projects should be completed on time, also on budget, and the quality should meet the standards. When you have difficulties working with your suppliers due to the sanctions, you cannot be in the budget. Also, you cannot be on time. Sometimes you design based on some technical requirements and when some companies are not able to work with you, you have to change the vendor. So, you lose the quality especially when you need to change the specifications because of changing the vendor. Changing the vendor and adapting new technical specifications, increases the time and as a result the cost of our projects.

1.4- Can you provide examples of when these challenges have led to project delays or cost overruns?

For one of our automation projects in the railway industry, we started working with a German company, and then due to sanctions, they were not able to work with them. As a result, we tried to change to a Chinese system. Then, we found out that this Chinese company is not able to meet our requirements. In the end, we managed to supply the automation system from an Italian company with the technical requirements we needed. But, in the meantime, we lost precious time and had to bear extra costs.

2. The role of blockchain technology to address the problems and improve efficiency

2.1- To what extent are you familiar with Blockchain technology and its characteristics?

I am not familiar with blockchain in detail. I have only general informationI studies in some sources in recent years.

2.2- How can blockchain technology improve the efficiency of the supply chain in railway construction projects?

Since the blockchain is an independent system and does not belong to an organization, institute, or government, it could bring more clarity and the possibility of monitoring the

whole system. So, independency, clarity, and monitoring can help projects and systems, especially in Iran which is suffering from unclarity. It can expedite the process of supplying goods.

2.3- Are there any specific processes or areas in the supply chain in which blockchain technology can make a major impact?

One point that I can add, and I think is very important is that, at the moment in Iran, it is very important to contact directly to the vendors abroad. We are doing it through some middle companies.

2.4- Are there any potential drawbacks or limitations of using blockchain technology in the railway industry?

I do not see any drawbacks. But the limitation could be lack of proper IT infrastructure. But it is not a major problem.

3. The barriers and hurdles of implementing blockchain technology in the railway industry

3.1- What are the biggest barriers or hurdles to implementing blockchain technology in the railway industry?

Some companies are not willing to implement the blockchain because they are benefiting from unclarity.

3.2- Are there any regulatory or legal challenges that could make it difficult to adopt blockchain technology?

In Iran, there is not any regulations or written principles. But. Maybe in some areas like cryptocurrency, there are some regulations, but regarding these new applications of blockchain, I think there are still no regulations.

3.3- What would be required to convince stakeholders in the railway industry to adopt blockchain technology? Each stakeholder has their own interest and also their readiness to implement and adopt this technology. In general, they need to educate younger generations and guarantee the benefit of stakeholders. They also should lessen the fear of some companies which are more traditional. It should be clarified how it works, and how it could be beneficial. All these needs education and training. Some companies are government-related companies that have to comply with regulations and principles. Regarding such companies, I think it is more complicated and difficult to convince them to change their procedures.

3.4 Are there any concerns around data privacy or security when it comes to using blockchain technology in the railway industry? If so, how can these concerns be addressed?

I believe like any other procedure, there is of course some concerns. I have not faced or thought about them, but I think these concern could be easily addressed.

Appendix 3: Table of Codes

Code	Sub-cluster	Main Cluster	Statement/Response
Budget Limitation	Budgetary Challenges	Ps & Cs	Failure to provide necessary liquidity by clients and as a result delay in payments and consequently delay in receiving equipment
Budget Limitation	Budgetary Challenges	Ps & Cs	Providing the budget is the biggest challenge. We have to pay a deposit and also pay our suppliers during the manufacturing process.
Budget Limitation	Budgetary Challenges	Ps & Cs	Financial condition of the employer that makes it difficult when we must pay ourselves for our projects.
Budget Limitation	Budgetary Challenges	Ps & Cs	Delays in payment and lack of sufficient funds cause long delays in projects and damage our image in the eyes of vendors who are now working with us.
Budget Managment	Budgetary Challenges	Ps & Cs	On the one hand, the client, the Tehran metro company, is facing serious financial problems. On the other hand, Contractors could also be guilty themselves. It may be that the deposit is paid, but the contractors are not able to manage this budget. Sometimes some systems could be purchased at the end of the projects, while the contractor purchases them at the beginning. For example, SCADA System is not a system which is needed to be bought soon but, there are other systems which are more essential to be purchased first. The contractor should manage these things.
Financial Issues	Budgetary Challenges	Ps & Cs	These delays were accompanied by a severe inflation in the price of the equipment and caused us to completely change the contract and choose a new contract because it was not cost-effective for the client.
Financial Issues	Budgetary Challenges	Ps & Cs	We face to several issues like financial issues
Financial Issues	Budgetary Challenges	Ps & Cs	Lack of financial resources and indiscriminate and unplanned injection of financial resources
Financial Issues	Budgetary Challenges	Ps & Cs	Exchange rate fluctuations, high inflation and constant and daily price changes that cause Many claims are made by contractors
Financial Issues	Budgetary Challenges	Ps & Cs	due to the drastic changes in the exchange rate, as well as the delay in the payment and completion of the advance payment, the contractor did not succeed in placing the order on time, and the main manufacturer did not succeed in placing the order due to the inflation in his country increased the prices. Also, the

			prices of domestic equipment and services were adjusted due to inflation and salary increases.
Financial Issues	Budgetary Challenges	Ps & Cs	there are middlemen in between, some of which do not work based on SWIFT. Each of these intermediaries has its own method and solution. These different methods cause us to have a long delay in transferring money.
Financial Issues	Budgetary Challenges	Ps & Cs	restrictions on money transfers
Financial Issues	Budgetary Challenges	Ps & Cs	The customer cannot pay us and consequently we cannot pay our suppliers, causing project delays in some of our projects such as Tehran Metro Line 6.
Financial Issues	Budgetary Challenges	Ps & Cs	Our dependence on Vendors means that we are unable to manage the costs and expenses of the project. We enter into a contract and buy a product whose supplier increases its price, and we have to pay extra for it.
Financial Issues	Budgetary Challenges	Ps & Cs	We had a supplier who was supposed to supply the batteries for us, but during the project period, due to the increased dollar price and the risks involved, he doubled the price of the goods to cover the risk of inflation. So, what we are expecting is costing us A rials, costs us 2 A rials and there is nothing we can do about it. Since we had to buy this system, we had to pay twice the cost and in practice we fail to manage costs.
Financial Issues	Budgetary Challenges	Ps & Cs	In practice, money is a very important factor. Until our contractors do not receive their money, they cannot contact their suppliers
Financial Issues	Budgetary Challenges	Ps & Cs	If no money is not made available and there is inflation, goods usually become more expensive. It could be problematic for Client as well as contractor.
Financial Issues	Budgetary Challenges	Ps & Cs	The main challenges related to the supply chain based on their importance are unfavorable financial conditions and unpredictability of financing timing
Corruption	Compliance Challenges	Ps & Cs	and corruption
Laws and Regulations	Compliance Challenges	Ps & Cs	some governmental rules in the country
Laws and Regulations	Compliance Challenges	Ps & Cs	we have several limited rules from our government side. The biggest one is custom clearance related rules. When we need to import some high technological final products, we should face a big challenge in our custom clearance ports.
Laws and Regulations	Compliance Challenges	Ps & Cs	Compulsion to use domestic producers and limitation in choosing the seller and capacity limitation of domestic producers
Laws and Regulations	Compliance Challenges	Ps & Cs	Ongoing regulation changes to release products at customs
Laws and Regulations	Compliance Challenges	Ps & Cs	there were times when there was a new regulation issued for the product we were expecting to receive at customs
Laws and Regulations	Compliance Challenges	Ps & Cs	Although all required documents to release the product were prepared, we had to go into a new process due to the new released regulation. This could include extra lab and testing phases to make sure the national standards are met. This long lasting testing process kept us behind the project and made us pay more than expected for the testing costs.
Laws and Regulations	Compliance Challenges	Ps & Cs	at the moment we have a rule which requires the companies to use domestic potentials and domestic

			suppliers. As a result, although we have competent suppliers throughout the world who are willing to work with us, but we must make a contract with domestic suppliers in order to support them.
Laws and Regulations	Compliance Challenges	Ps & Cs	However, since the price is cheaper, and a domestic company should get support from the industry, we need to make a contract with them. If there is any delay or quality drop, we can't complain because there is a monopoly in the market.
Sanctions	Compliance Challenges	Ps & Cs	Also, because of some issues like international sanctions in our country, we face a big issue called delivery time.
Sanctions	Compliance Challenges	Ps & Cs	- Sanctions
Sanctions	Compliance Challenges	Ps & Cs	Restrictions on money transfers
Sanctions	Compliance Challenges	Ps & Cs	Severe restrictions in choosing foreign suppliers due to sanctions
Sanctions	Compliance Challenges	Ps & Cs	As you should know, the big challenge is sanctions and limitations related to sanctions. The root cause for all challenges are sanctions and political issues. Other issues are somehow related to these sanctions.
Sanctions	Compliance Challenges	Ps & Cs	When you have difficulties working with your suppliers due to the sanctions, you cannot be in the budget. Also, you cannot be on time.
Sanctions	Compliance Challenges	Ps & Cs	If I want to say that there is a priority, the first is the sanctions. Iran is a country subject to sanctions. It's difficult to get the materials
Sanctions	Compliance Challenges	Ps & Cs	In these cases, the relationship and communication with the manufacturers is the biggest challenge.
Sanctions	Compliance Challenges	Ps & Cs	Another issue is guarantee and some factory tests which we have with abroad suppliers. Although there are some domestic companies that gives us services relating these goods, but the quality of services is not high and we cannot rely on.
Sanctions	Compliance Challenges	Ps & Cs	As an example, we made a contract with Honeywell and at the end, they did not provide us with a license instead of a dongle. It caused us not to complete the project. We made the contract with this company because in an international level, we do not have bargaining power.
Sanctions	Compliance Challenges	Ps & Cs	Currently, international problems caused by sanctions, money transfer issues, and limiting domestic regulations which partly indicates the limit in countries monetary resources. This limitation causes the cooperation between Iran and top internationally renowned brands be very limited and, in some cases, impossible.
Sanctions	Compliance Challenges	Ps & Cs	Since our relations with other stakeholders are not based on international protocols and conventional relations (unlike two European countries, for example) and due to specific geographical and political conditions, our work is very difficult in terms of relations with other countries. It significantly increases the time and cost of the project.
Sanctions	Compliance Challenges	Ps & Cs	While these money transfers can be done in one day, due to sanctions there are middlemen in between
Sanctions	Compliance Challenges	Ps & Cs	We even experienced one case where the money was transferred, but Sechron could not withdraw the money due to sanctions issues and it took 6 months to reach them.
Sanctions	Compliance Challenges	Ps & Cs	Restrictions due to sanctions
Sanctions	Compliance Challenges	Ps & Cs	The procurement of raw materials is problematic for manufacturers due to the sanctions.

Sanctions	Compliance Challenges	Ps & Cs	The first is sanctions and because of the sanctions, a restriction on the suppliers who work with us.
Sanctions	Compliance Challenges	Ps & Cs	Subject to sanctions that prevent us from reaching out to suppliers and payment to suppliers against the goods and services we receive.
Sanctions	Compliance Challenges	Ps & Cs	finding reliable and high-quality international companies to work with us when our industry is under sanctions
Finding Suppliers	Suppliers	Ps & Cs	One is choosing suppliers. There are some suppliers that are not compliant with our standards. There are suppliers that we needed to ask them to meet the highest standards to be able to bring them to our vendor list.
Finding Suppliers	Suppliers	Ps & Cs	Yes, I recall the time that we were evaluating the suppliers for some LV Panels and we had a hard time finding the supplier to provide us with the full compliant, the certificate for us to put them in our vendor list. So, we had to go with other vendors that were not in the list of our client. We went through a lot to convince the Metro to accept them at their vendor list.
Finding Suppliers	Suppliers	Ps & Cs	Sometimes you design based on some technical requirements and when some companies are not able to work with you, you have to change the vendor. So, you lose the quality especially when you need to change the specifications because of changing the vendor
Finding Suppliers	Suppliers	Ps & Cs	The second Challenge is convincing the client's consultant when we want to bring a new vendor in our vendor list. We should argue a lot in this regard.
Finding Suppliers	Suppliers	Ps & Cs	In my experience, the number of suppliers of some devices is problematic. For example, when it comes to third rails or DC switchgear, we only have a few suppliers who meet our requirements.
Finding Suppliers	Suppliers	Ps & Cs	limitations on the number of suppliers mean that you cannot have more leeway
Finding Suppliers	Suppliers	Ps & Cs	for example, the suppliers of busbars or third-party busbars or DC switchgear are limited. These providers are also very limited on an international level. Therefore, we cannot have multiple options and must get along with the existing suppliers and move on. We had such problems in Tehran Metro Line 3 Project as well as Isfahan Metro Line 2.
Finding Suppliers	Suppliers	Ps & Cs	finding reliable domestic suppliers who are able to meet the project requirements
Priority Changes	Project Hurdles	Ps & Cs	Another challenge is timing. A timetable and priority of execution will be given to the contractors initially, but this timetable is subject to change. The relationship between client and contractor should be designed in such a way that they can cope with these time changes together. Also, the contractor might not have a strong engineering or execution team.
Project Delays	Project Hurdles	Ps & Cs	When it comes to the success of the projects, I would say the time wise. These kind of challenges are going to impact the overall success of the project. When we are not able to get the projects on site as the day they supposed to ship the product, you are kind of overseeding the time.
Project Delays	Project Hurdles	Ps & Cs	As a result, the money, time and MOV are very important things we need to deal with. When you are not satisfying customers, so you are not able to completing the project. I would say cost wise, timewise impacting the success of the projects.
Project Delays	Project Hurdles	Ps & Cs	We had to go through a big process; give them a tour for signing some kind of agreement with 1them. Just give them the crazy warranty to make them sure if something happened to the projects

Project Delays	Project Hurdles	Ps & Cs	From a planner's perspective, the biggest challenge is project time. The time allotted for a project is limited due to time constraints in railway projects. These projects must be done in a certain time with a certain budget. But, due to the problems in the field of equipment supply, this time is longer and imposed a lot of additional costs on the project
Project Delays	Project Hurdles	Ps & Cs	delivery times
Project Delays	Project Hurdles	Ps & Cs	Creating a delay in the schedule considered by the clients
Project Delays	Project Hurdles	Ps & Cs	Increase in the cost of the project (due to the increase in time and the lack of competition in the supply of equipment)
Project Delays	Project Hurdles	Ps & Cs	Time delays caused by reasons beyond the control of the company such as project site not being ready.
Project Delays	Project Hurdles	Ps & Cs	Manufacturing delays: they may change the shipping date due to quality issues or their potential shortages
Project Delays	Project Hurdles	Ps & Cs	Port congestion and delays in unloading the cargo
Project Delays	Project Hurdles	Ps & Cs	Shortages of critical basic materials & consequently their rising prices
Project Delays	Project Hurdles	Ps & Cs	Changing the vendor and adapting new technical specifications, increases the time and as a result the cost of our projects
Project Delays	Project Hurdles	Ps & Cs	Changing the vendor and adapting new technical specifications, increases the time and as a result the cost of our projects
Project Delays	Project Hurdles	Ps & Cs	time of the project will increase
Project Delays	Project Hurdles	Ps & Cs	The completion of the project will be affected. This means that we cannot meet the deadline. The projects remain open, and the customer does not complete the project because, for example, you cannot supply a spare part for a system and the project is not completed in practice
Project Delays	Project Hurdles	Ps & Cs	Since our relations with other stakeholders are not based on international protocols and conventional relations (unlike two European countries, for example) and due to specific geographical and political conditions, our work is very difficult in terms of relations with other countries. It significantly increases the time and cost of the project.
Project Delays	Project Hurdles	Ps & Cs	for example, the suppliers of busbars or third-party busbars or DC switchgear are limited. These providers are also very limited on an international level. Therefore, we cannot have multiple options and must get along with the existing suppliers and move on. We had such problems in Tehran Metro Line 3 Project as well as Isfahan Metro Line 2.
Project Delays	Project Hurdles	Ps & Cs	The customer cannot pay us and consequently we cannot pay our suppliers, causing project delays in some of our projects such as Tehran Metro Line 6.
Project Delays	Project Hurdles	Ps & Cs	Sometimes there is a lack of electricity or gas for our suppliers and hence our projects are delayed
Project Delays	Project Hurdles	Ps & Cs	Timing of the supply, which we cannot exactly schedule and count on
Project Delays	Project Hurdles	Ps & Cs	These problems and challenges increase the risk of project failure. This also increases the time we need to complete the project.
Project Delays	Project Hurdles	Ps & Cs	there are systems such as clocks or closed-circuit cameras, which were not accepted by customers. This means lower quality and more costs and delays in the project.
Quality Problems	Project Hurdles	Ps & Cs	Reducing the quality of the final product

Quality Problems	Project Hurdles	Ps & Cs	Sometimes you design based on some technical requirements and when some companies are not able to work with you, you have to change the vendor. So, you lose the quality especially when you need to change the specifications because of changing the vendor
Quality Problems	Project Hurdles	Ps & Cs	Another issue is the quality. The client can say that because of supplying goods from a domestic company, the quality is reduced, and I cannot take on the project.
Quality Problems	Project Hurdles	Ps & Cs	in one of our projects, we bought the clock system from a domestic manufacturer and encountered many soft and hard defects
Quality Problems	Project Hurdles	Ps & Cs	for example, the suppliers of busbars or third-party busbars or DC switchgear are limited. These providers are also very limited on an international level. Therefore, we cannot have multiple options and must get along with the existing suppliers and move on. We had such problems in Tehran Metro Line 3 Project as well as Isfahan Metro Line 2.
Quality Problems	Project Hurdles	Ps & Cs	Quality of packaging, transport (in route and at destination) and unloading. Also, the quality of the final product that we receive is one of our challenges.
Quality Problems	Project Hurdles	Ps & Cs	The theme that says whether we are buying specifically what we need and whether what we are buying meets the needs of the project. our technical and engineering knowledge is not so advanced that we have different choices for sourcing our needs. We are currently buying based on our suppliers. So, we are technologically restricted by the suppliers. The money transfer or better the financial schedule is too problematic. There is a risk that after entering into a contract we may or may not receive the goods and services and also after sales services.
Quality Problems	Project Hurdles	Ps & Cs	Failure to cooperate with high-quality companies and failure to provide high-quality equipment and services leads to a decrease in the final quality of projects. This poor quality itself can cause a delay in delivery because the main client does not want to take over the project due to low quality.
Quality Problems	Project Hurdles	Ps & Cs	there are systems such as clocks or closed-circuit cameras, which were not accepted by clients. This means lower quality and more costs and delays in the project.
Cost Overruns	Project Hurdles	Ps & Cs	As a result, the money, time and MOV are very important things we need to deal with. When you are not satisfying customers, so you are not able to completing the project. I would say cost wise, timewise impacting the success of the projects. ¶
Cost Overruns	Project Hurdles	Ps & Cs	So, we had to pay a lot of money in order to convince the supplier
Cost Overruns	Project Hurdles	Ps & Cs	We are the one who is going to pay all the costs and delays if they occurred.
Cost Overruns	Project Hurdles	Ps & Cs	due to the problems in the field of equipment supply, this time is longer and imposed a lot of additional costs on the project. Well, for all these things, you have to increase your period of need, and this will make all your expenses multiply.
Cost Overruns	Project Hurdles	Ps & Cs	When the project time increases, it causes you to incur a lot of side costs including the cost of human resources and the cost of equipment which is needed periodically for maintenance of a project, the cost of facilities provided for the project for a specific period of time
Cost Overruns	Project Hurdles	Ps & Cs	we will have to incur increased costs especially in their logistics and customs clearance phase

Cost Over-runs	Project Hurdles	Ps & Cs	Changing the vendor and adapting new technical specifications, increases the time and as a result the cost of our projects
Cost Over-runs	Project Hurdles	Ps & Cs	he price and time of the project will increase
Cost Over-runs	Project Hurdles	Ps & Cs	Sometimes the price, increases up to 60% of the main price.
Cost Over-runs	Project Hurdles	Ps & Cs	As a result of these defects, we cannot charge the client appropriately and our profit has been decreased.
Cost Over-runs	Project Hurdles	Ps & Cs	Since our relations with other stakeholders are not based on international protocols and conventional relations (unlike two European countries, for example) and due to specific geographical and political conditions, our work is very difficult in terms of relations with other countries. It significantly increases the time and cost of the project.
Cost Over-runs	Project Hurdles	Ps & Cs	for example, the suppliers of busbars or third-party busbars or DC switchgear are limited. These providers are also very limited on an international level. Therefore, we cannot have multiple options and must get along with the existing suppliers and move on. We had such problems in Tehran Metro Line 3 Project as well as Isfahan Metro Line 2.
Cost Over-runs	Project Hurdles	Ps & Cs	Also, price increase. The prices change regularly. In many cases, the rules and regulations change.
Cost Over-runs	Project Hurdles	Ps & Cs	there are systems such as clocks or closed-circuit cameras, which were not accepted by customers. This means lower quality and more costs and delays in the project.
Middelmen	Intermediaries	Ps & Cs	We need to build these relationships through some middle companies or some layers. Therefore, our technical questions and technical concerns about the supplied equipment need to pass through these layers to reach the main manufacturer.
Middelmen	Intermediaries	Ps & Cs	there are middlemen in between, some of which do not work based on SWIFT. Each of these intermediaries has its own method and solution. These different methods cause us to have a long delay in transferring money.
Choosing Suppliers	Interactions	BC solutions	If I want to mention other points, I can say vendor management, contract management and project management can be done efficiently inside the supply chain.
Choosing Suppliers	Interactions	BC solutions	I can either enter to relationship with the same partner or omit it and find another vendor. In this way, you can create a chain of companies which are all qualified and as time goes on, you can store more information and expand the chain
Choosing Suppliers	Interactions	BC solutions	For example, we have a supplier for our FAS system, and we had some contracts with them. So, we have a lot of technical and contractual record of cooperation, and it makes it easier to communicate with them for our next projects either in corporation level or between persons
Choosing Suppliers	Interactions	BC solutions	Also assess and rate the companies you work with as a supplier.
Simplifying International Interactions	Interactions	BC solutions	One point that I can add, and I think is very important is that, at the moment in Iran, it is very important to contact directly to the vendors abroad
Simplifying International Interactions	Interactions	BC solutions	Then a transparency facility that can link our industrial circuit to the international circuit, giving us the opportunity to expand our business and export our products to other countries.
Simplifying Money Transfer	Interactions	BC solutions	Also, a decentralized platform is created between the customer and the supplier with that the process of supply and payment can be facilitated.

Simplifying Money Transfer	Interactions	BC solutions	Financial transfers can be made through blockchain
Simplifying Money Transfer	Interactions	BC solutions	Money transfer can be done more easily on the platform of blockchain, especially for less developed countries that have fewer facilities to accelerate money transfer and reduce the monopoly of strong money.
Simplifying Money Transfer	Interactions	BC solutions	It can accelerate the process of transferring.
Setting consensus rules	Interactions	BC solutions	When it comes to design of something, they have to make sure that everything is on the basis that all parties are agreed upon. I would say. It is going to change the whole world of supply chain a lot.
Data Accesibility	Data Integrity & Transparency	BC solutions	As I know in Blockchain, you have access to every little information or every little bit of data of supply chain.
Data Accessibility	Data Integrity & Transparency	BC solutions	using Blockchain, all parties such as warehouses, manufacturers, suppliers, and distribution centers connect to each other sharing the records that are accessible to everyone within the network.
Data Accessibility	Data Integrity & Transparency	BC solutions	Another benefit is knowledge management. For example, you perceive that there are some contracts in this chain, and I can see through the draft of those contracts and we can make predictions for our project and see the lessons we've learned from others.
Data Security	Data Integrity & Transparency	BC solutions	But security wise and privacy wise, I feel like the Blockchain is kind of to my knowledge is super secure.
Data Security	Data Integrity & Transparency	BC solutions	The transfer of confidential information can be done on the blockchain platform
Data Security	Data Integrity & Transparency	BC solutions	Information security and creating reliable access for all parties Involved in the project
Data Security	Data Integrity & Transparency	BC solutions	Transparency, traceability, and security can the major impacts on supply chain
Data Security	Data Integrity & Transparency	BC solutions	Finally, Immutability allows all stakeholders to be sure that the data is untampered and reliable.
Decentralized System	Data Integrity & Transparency	BC solutions	Blockchain's ability to decentralize and verifying information in the supply chain can be helpful.
Decentralized System	Data Integrity & Transparency	BC solutions	Existence of decentralized structure
Decentralized System	Data Integrity & Transparency	BC solutions	Since the blockchain is an independent system and does not belong to an organization, institute, or government, it could bring more clarity and the possibility of monitoring the whole system. So, independency, clarity, and monitoring can help projects and systems, especially in Iran which is suffering from unclarity. It can expedite the process of supplying goods.
Decentralized System	Data Integrity & Transparency	BC solutions	Generic blockchain features like transparency and decentralization can also be helpful.
Reliability of Data	Data Integrity & Transparency	BC solutions	Since records are not able to be easily erased or edited, using blockchain brings more transparency and trust into the whole supply chain process.
Reliability of Data	Data Integrity & Transparency	BC solutions	In a professional level, if we want to avoid long-term negotiations and many meetings, we can make smart contracts and simplify these processes. Everything could be brief and reliable inside Blockchain.
Secure Platform	Data Integrity & Transparency	BC solutions	As I mentioned before, it can help us facilitating in payments and financial processes and provide us with a secure platform.
Secure Platform	Data Integrity & Transparency	BC solutions	The processes related to holding tenders can be done on the platform of blockchain and create good confidence for the contractors participating in the tender.

Secure Platform	Data Integrity & Transparency	BC solutions	Complex encryption and the impossibility of information theft
Tracebility	Data Integrity & Transparency	BC solutions	Another issue is transaction and movement of goods that is traceable by all the stakeholders.
Tracebility	Data Integrity & Transparency	BC solutions	blockchain can reduce the time-consuming process of customs clearance, and by creating unique encryptions on the goods entering the customs, the information of the cargos imported and exported from the customs will be easier to control,
Tracebility	Data Integrity & Transparency	BC solutions	For some products we require an international certificate from an international laboratory, and it is important for us to track our suppliers to ensure they always source their materials from verified and high quality suppliers.
Tracebility	Data Integrity & Transparency	BC solutions	our supplier says when we signed the contract the dollar was 3000 and now it's 6000 and the raw materials, I want to buy are getting more and more expensive. Therefore, we must agree to an increased price. This claim may not be true. It could be that the supplier had previously bought the raw materials and now only wants to abuse this inflation and make profit from this vague atmosphere. But if this process is defined on the blockchain platform, everything is traceable
Tracebility	Data Integrity & Transparency	BC solutions	And about the quality, for example, we have a contract, and the supplier outsources the goods to a Chinese company that makes a lower quality product. But in a smart contract and within the blocks, we can track each moment and see if it produces the good itself or outsources it.
Tracebility	Data Integrity & Transparency	BC solutions	Transparency, traceability, and security can the major impacts on supply chain
Tracebility	Data Integrity & Transparency	BC solutions	The use of blockchain makes it clear from the start how the manufacturing process works.
Tracebility	Data Integrity & Transparency	BC solutions	Traceability enables buyers and other stakeholders such as contractors and customers to ensure the authenticity of goods, raw materials and downstream producers.
Transparency	Data Integrity & Transparency	BC solutions	The transparency that it provides in transactions. When you want to supply materials and equipment, you can track this process. Stakeholders can track this process.
Transparency	Data Integrity & Transparency	BC solutions	As I know in Blockchain, you have access to every little information or every little bit of data of supply chain. So, when everything is clear, everything is in hand, no matter, you are which part of supply chain.
Transparency	Data Integrity & Transparency	BC solutions	As I face this issue in my job, when you do not know about the suppliers of your supplier's issues, so you cannot be ready for issues that will occur in supply chain later. I think Blockchain itself because of its specific character which is it's transparency, it will be a major impact.
Transparency	Data Integrity & Transparency	BC solutions	Blockchain can be useful in creating unique identifiers for goods and help contractors in purchasing genuine goods and avoiding fake goods.
Transparency	Data Integrity & Transparency	BC solutions	Creating transparency in the information related to the supply chain
Transparency	Data Integrity & Transparency	BC solutions	Blockchain technology can provide real-time visibility and tracking of goods and products throughout the entire supply chain, from production to distribution to end consumers. This helps to increase transparency and trust between different parties in the supply chain.
Transparency	Data Integrity & Transparency	BC solutions	A block that I can reach in order to meet my technical, financial, and contractual needs in a transparent way.

Transparency	Data Integrity & Transparency	BC solutions	Generic blockchain features like transparency and decentralization can also be helpful.
Transparency	Data Integrity & Transparency	BC solutions	Transparency between partners
Transparency	Data Integrity & Transparency	BC solutions	And about the quality, for example, we have a contract, and the supplier outsources the goods to a Chinese company that makes a lower quality product. But in a smart contract and within the blocks, we can track each moment and see if it produces the good itself or outsources it.
Transparency	Data Integrity & Transparency	BC solutions	Transparency, traceability, and security can the major impacts on supply chain
Transparency	Data Integrity & Transparency	BC solutions	Which companies has produced the materials and the cables and in what quality also become clear.
Transparency	Data Integrity & Transparency	BC solutions	First of all through transparency. Transparency helps a system to be agile.
Real-Time Monitoring	Data Integrity & Transparency	BC solutions	Blockchain technology can provide real-time visibility and tracking of goods and products throughout the entire supply chain, from production to distribution to end consumers.
Real-Time Monitoring	Data Integrity & Transparency	BC solutions	In terms of timing, currently we can only request a production milestone before delivery, or at most inspect the production line regularly during manufacture, which is not enough. If I would like to describe it with an example: We once had a problem with one of the suppliers who had promised us to prepare 45 km of cable in a certain time. But he couldn't, and that could damage our image at the political level. But with blockchain, we can improve that timing with real-time tracing.
Real-Time Monitoring	Data Integrity & Transparency	BC solutions	And about the quality, for example, we have a contract, and the supplier outsources the goods to a Chinese company that makes a lower quality product. But in a smart contract and within the blocks, we can track each moment and see if it produces the good itself or outsources it.
Real-Time Monitoring	Data Integrity & Transparency	BC solutions	There will be real-time monitoring of processes such as production, shipping, delivery and payment.
Deleting Corruption	Preventing Misconduct	BC solutions	On the other hand, some companies are no longer limited to making very high profits.
Deleting Corruption	Preventing Misconduct	BC solutions	One is that it can prevent corruption. The corruption we do not like, but we have to get along with it
Deleting Corruption	Preventing Misconduct	BC solutions	Also, with transparency it provides, corruption does not take place or is limited.
Equal Chance for New Suppliers	Preventing Misconduct	BC solutions	I believe in using Blockchain because it helps to clear every single part of supply chain to be useful.
Equal Chance for New Suppliers	Preventing Misconduct	BC solutions	blockchain offers the possibility that all suppliers who want to work and deliver, but do not have data on whether there is a customer for them or not, can enter this chain and reap the benefits. This not only means advantages for buyers, but suppliers can also present themselves within this infrastructure. Certainly, this technology increases competition between vendors. There is certainly room for not enough well-known providers who are new to the market. These vendors are willing to work with higher quality and lower price than other renown vendors. In general, this could be an infrastructure for approval of validation of vendors.
Equal Chance for New Suppliers	Preventing Misconduct	BC solutions	It also provides a platform for a competitive marketplace by sharing data and giving all stakeholders, such as new vendors, the same tools for doing business.

Fraud Prevention	Preventing Misconduct	BC solutions	it can be an effective help in preventing the smuggling of goods in Customs and under-declarations or defective declarations
Fraud Prevention	Preventing Misconduct	BC solutions	our supplier says when we signed the contract the dollar was 3000 and now it's 6000 and the raw materials, I want to buy are getting more and more expensive. Therefore, we must agree to an increased price. This claim may not be true. It could be that the supplier had previously bought the raw materials and now only wants to abuse this inflation and make profit from this vague atmosphere. But if this process is defined on the blockchain platform, everything is traceable.
Omiting Middlemens	Preventing Misconduct	BC solutions	Preventing the entry of middlemen and reducing the cost of supplying equipment
Omiting Middlemens	Preventing Misconduct	BC solutions	It can also reduce the number of dealers involved in a supply chain process resulting in less fraud.
Omiting Middlemens	Preventing Misconduct	BC solutions	It can bypass the role of middlemen and decrease the time and consequently the cost of the project.
Omiting Middlemens	Preventing Misconduct	BC solutions	By interfering with and minimizing the role of banks, intermediaries and middlemen, both sides of the negotiations can benefit.
Facilitating Processes	Project Management	BC solutions	To me everythings would be superorganized and super disciplined and it is going to facilitate all aspects of the supply chain, not only just one aspect. From the start to the end
Facilitating Processes	Project Management	BC solutions	Also, a decentralized platform is created between the customer and the supplier with that the process of supply and payment can be facilitated.
Facilitating Processes	Project Management	BC solutions	Simplifying the supply process through smart contracts
Facilitating Processes	Project Management	BC solutions	In a professional level, if we want to avoid long-term negotiations and many meetings, we can make smart contracts and simplify these processes. Everything could be brief and reliable inside Blockchain.
Facilitating Processes	Project Management	BC solutions	Interaction between stakeholders becomes easier and facilitated.
Inventory Managemenet	Project Management	BC solutions	Blockchain can be used to track inventory levels and optimize inventory management processes, reducing bottlenecks, inventory costs and improving supply chain efficiency.
Project Management Agility	Project Management	BC solutions	it can boost the teamwork in a project. It means that instead of waterfall method, it uses agile project management method. It means, instead of finishing one step and getting the approval of the client, this approval could be obtained while this step is being currently done. As a result, it is an effective tool for project management.
Project Management Agility	Project Management	BC solutions	When everything is clear, you can be aware about any penalties or any issues that will appear in supply chain and you face them.
Project Management Agility	Project Management	BC solutions	It causes the project management to become agile. This technology can improve our decision support system. The output of this technology can be used in a decision support system.
Project Management Agility	Project Management	BC solutions	All stakeholders can see what is going on in the project and when a problem is happened, they can manage the problem in time.
Quality Improvement	Project Management	BC solutions	Blockchain can be used to track the quality of products as they move through the supply chain, enabling faster identification and removal of defective products, reducing waste and improving customer satisfaction.
Quality Improvement	Project Management	BC solutions	And about the quality, for example, we have a contract, and the supplier outsources the goods to a Chinese company that makes a lower quality product.

			But in a smart contract and within the blocks, we can track each moment and see if it produces the good itself or outsources it.
Quality Improvement	Project Management	BC solutions	It can ensure the client about the quality of the good that it buys. The client cannot regularly inspect the goods in production line. There could be a platform on which our contractors stay in contact with some big suppliers and row material providers. It could lead to quality improvement.
Reducing Costs	Project Management	BC solutions	Having access to transparent records of supply chain processes, Blockchain can reduce the risk of non-compliance and related penalties.
Reducing Cost Estimation Time	Project Management	BC solutions	if we need to bid on a tender, or for some reason we want a cost estimate for our project, we can use this technology to do a general cost estimate.
Reducing Contract Signing Time	Project Management	BC solutions	On the one hand, a company can find partners and make contracts easier.
Reducing Contract Signing Time	Project Management	BC solutions	You shorten the time for contract negotiations. Partners can more easily achieve a common goal
Reducing Contract Signing Time	Project Management	BC solutions	It can increase contract signing speed.
Reducing Contract Signing Time	Project Management	BC solutions	Thirdly, Smart contracts help by speeding up interactions and financial transactions.
Reducing Delivery Time	Project Management	BC solutions	Ideally, the transparency is so high that the projects can be completed very easily and the time for project delivery is drastically reduced.
Reducing Delivery Time	Project Management	BC solutions	This technology can act like an automation system; It can mechanize a process and therefore this technology can play a crucial role in shortening the distance between production and delivery
Lack of Experts in Blockchain	Infrastructural Barriers	Barriers/Limits	there is no expert in blockchain technology.
Lack of Experts in Blockchain	Infrastructural Barriers	Barriers/Limits	We also need a superintendent to review the data shared by partners on the blockchain.
Lack of Experts in Blockchain	Infrastructural Barriers	Barriers/Limits	we have little expertise in this area.
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	The current limitations of using this technology are mostly due to the lack of infrastructure
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	But the limitation could be lack of proper IT infrastructure. But it is not a major problem.
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	Hardware and software infrastructure may be required. I don't know exactly what infrastructure and foundations we need, but there are certainly some and if we want to implement Blockchain in the railway industry.
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	Any technology that wants to come to market needs a set of facilities and infrastructure, and the government must provide these facilities. We need an assessment system. Several standards need to be defined. All services and devices must reach an acceptable level such as different ISOs.
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	Some use new technologies, while there are companies that hardly use a computer. This makes it difficult to bring all these companies together on one platform.
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	Hardware-wise, part of the blockchain implementation in the industry is based on the Internet of Things. The basis of the IOT is now the internet itself. And we

			have internet restrictions in our country. This means that our internet facilities have not been increased due to political and security restrictions. Internet speed is low. We don't have 5G internet. Therefore, we cannot collect the data online.
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	As limitation, I can mention lack of international platform
Lack of Infrastructures	Infrastructural Barriers	Barriers/Limits	I can name the lack of comprehensive and integrated laws, regulations and standards among different businesses and different countries.
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	And also, you have to train them
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	You are going to let them to think for a while, so that you can see what is going to be the bad consequences of this technology to apply in this industry.
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	The topic of blockchain is a complex concept and its implementation requires a complete and correct explanation among the members who use it in organizations, and I think its implementation requires the creation of an easy-to-use software platform.¶
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	lack of awareness of company managers about the benefits of this technology
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	It also requires training and educating staff on how to use this technology.
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	Since this is new, the biggest weakness is the unfamiliarity of our partners with this technology.
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	Unfamiliarity of those people who are involved in this industry and their resistance to the changes.
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	robably not all partners are familiar with blockchain.
Lack of Knowdedge	Infrastructural Barriers	Barriers/Limits	not familiarity of all players in supply chain
Convincing Users	Infrastructural Barriers	Barriers/Limits	When you are introducing a new technology to an old- fashioned industry, it is very hard to convince people to get along people. Changing the people's way of thinking is super hard.
Convincing Users	Infrastructural Barriers	Barriers/Limits	Some people in railway industry do not want to change anything. They just go with the way they have been working with it. So, there is no need to change anything that has been working. So, convincing those narrow-minded and silid- minded is very hard.
Convincing Users	Infrastructural Barriers	Barriers/Limits	I would say convincing the top managers or the top guns
Convincing Users	Infrastructural Barriers	Barriers/Limits	I would say the biggest barrier is just convincing people and making sure this technology is not going to cost us a fortune
Needs Time to Understand It	Technical	Barriers/Limits	It takes time for organizations to see how blockchain can help them with more efficiency and how it is better from other existing cheaper technologies.
Needs Time to Understand It	Technical Barriers	Barriers/Limits	Another disadvantage is that blockchain is difficult and complicated.
Needs Time to Understand It	Technical Barriers	Barriers/Limits	This technology is very complex and requires a strong research and development unit to develop it.
Immutability	Technical Barriers	Barriers/Limits	Yes, data immutability can also be disadvantageous as there is no way to correct inaccurate data on a blockchain.
High Energy Consumption	Technical Barriers	Barriers/Limits	It is an expensive tech to implement, with high energy consumption.
Implementation Costs	Technical Barriers	Barriers/Limits	I am not sure how much we are going to spend in order to implement the technology to supply chain. Are we talking about a big money.
Implementation Costs	Technical Barriers	Barriers/Limits	It is an expensive tech to implement
Implementation Costs	Technical Barriers	Barriers/Limits	If we want to invest in facilities, we don't have the money

Implementation Costs	Technical Barriers	Barriers/Limits	I can mention the costly process of implementing blockchain
Blockchain not Supported	Technical Barriers	Barriers/Limits	Another limitation can be when a blockchain cannot be integrated with an existing ERP system, since they may not support the blockchain technology.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	Somebody or some businesses or some companies which are required to use Blockchain. They like to hide some data. Because their benefit is in ambiguity. As I explained before, Blockchain helps you to clear any part of supply chain. So, against this biggest character of Blockchain, some companies or some stakeholder's benefits will be jeopardized.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	One of the main obstacles to the implementation of blockchain in supply processes can be groups that see their interests at risk with the spread of this technology, for example intermediaries. or companies whose current business activity is based on cryptography, coding and similar tasks.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	Some companies are not willing to implement the blockchain because they are benefiting from unclarity.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	one of the hurdles that exist is the monopoly of some companies.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	. The first group that loses in these systems are the middlemen. Of course, we shouldn't call it corruption many times, but these are the services of companies that can bypass sanctions. Some of these companies will lose their advantage if we are in direct contact with suppliers through blockchain.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	one is that state economy does not allow transparency in processes. It means state economy is against transparency which is required in free market.
Middelmen Benefits	Regulatory Barriers	Barriers/Limits	some influences which come from corrupted authorities,
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	A negative point is the security of data as well as privacy. Specially since there are sensitive information in railway projects from maintenance record to customer data and also a part of technical design which could be controversial. An agreement should be reached by all parties about the data and security of the data could be one of the risks relating Blockchain.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	I think privacy of data is just only one concern about those companies that I said before.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	Also there is a threat of 51% attack in which data cannot be trusted.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	I think the main legal challenge and concern is to realize what jurisdiction is applicable when it comes to resolving disputes, because blockchain technology is global. For example, if a smart contract is hacked and funds are stolen, it is unclear who is liable for the loss.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	The downside is that the nodes of this network should trust each other and trust the network. There is no central supervisory authority that confirms the processes taking place in this chain. In countries like Iran which there is lack of clarity in, it could be a big drawback. You can begin a process and invest a lot and go ahead, but because of this lack, you end up having a big failure.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	I believe the know-how that bring about competitive advantage, should not be easily shared. If the partners want to share and access such data, they need to enter an agreement. It can be that the holders of this knowledge who are pioneers in the industry

			charge other partners for this valuable knowledge which is rational in my point of view.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	In the railway industry, which is not culturally advanced, there are of course concerns. The companies are afraid to share their data, but I don't know exactly what to do about it.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	One of the concerns is that our data will be misused by competitors, our customers, or our clients etc.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	In terms of new technologies, there would be always concerns. Even regarding some searching engines or communicational application like Google, there are still concerns. But the solution is setting laws and regulation in this regard. Laws in order to punish those who cause leakage in information. For people who implement this system should exist a system which always support them and they can refer to when there are legal problems or misuse.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	This trust in network structure is really important and very controversial in our country because there are some users that have access to lots of confidential information. Another point is the trust of stakeholders to each other. Whether they think that the data is sharing will be misused by others or not. If they trust each other, then they may share the data without having big concerns.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	Our company is an EPC contractor and 85% of a project's profit comes from supplying materials, goods, and services. As a result, a great part of our profit is in purchasing. And how we can buy these goods and services and how we can charge the client is one of our competitive advantages. If we enter a chain in which we share these data, it downsizes this advantage. Inside the chain, this data sharing could be not a big deal, but when this information will be shared outside the chain, it could jeopardize our competitive advantage.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	Data protection applies in particular to military concepts. But manufacturers also want their data to only pass through that chain and not be passed off-chain to competitors or companies who misuse that data.
Security and Privacy Concerns	Regulatory Barriers	Barriers/Limits	taking some competitive advantages of some companies and sharing them with all stakeholders which could demotivate companies from being innovative.
Standardization of Protocols and Policies	Regulatory Barriers	Barriers/Limits	One of the biggest hurdles is standardization of protocols and policies
Company Regulations	Regulatory Barriers	Barriers/Limits	There are also regulations within companies that oblige companies and organizations not to pass on their data. These regulations mean that the speed of implementation is restricted.
Company Regulations	Regulatory Barriers	Barriers/Limits	We are subject to investment restrictions and regulatory restrictions.
Company Regulations	Regulatory Barriers	Barriers/Limits	one limitation could be that the manufacturers do not want to pass on their data. There is technical knowledge that manufacturers or contractors have and for some reasons do not want to share it in a platform.
Cyber Security Laws	Regulatory Barriers	Barriers/Limits	I think the cyber security is going to be a big challenge for Blockchain in order to be implemented
Cyber Security Laws	Regulatory Barriers	Barriers/Limits	About Iran I cannot recall a regulation or law
Cyber Security Laws	Regulatory Barriers	Barriers/Limits	Definitely it is going to exist some concerns about privacy, but they are addressable by these IT experts.

Cyber Security Laws	Regulatory Barriers	Barriers/Limits	There are laws that say the smart contracts could not be implemented.
Cyber Security Laws	Regulatory Barriers	Barriers/Limits	Probably yes, because in most countries no rules have been defined for the use of blockchain, and also many companies may refuse to provide their information in blockchain format through some regulations, and join it due to lack of familiarity and avoiding unknown risks.
Existing Sanction	Regulatory Barriers	Barriers/Limits	And because of the existing sanctions, the clarity of these transactions could not be reached because of these limitations. And Also, there is limit on the transactions because of these sanctions.
Governmental Rules	Regulatory Barriers	Barriers/Limits	So, I think there is only one limitation of using Blockchain in supply chain which is governmental rules.
Governmental Rules	Regulatory Barriers	Barriers/Limits	The entry of this technology into the field of commercial exchanges and its globalization requires the approval of the governing laws
Governmental Rules	Regulatory Barriers	Barriers/Limits	Based on some politic and security reasons, there are some rules that explicitly prevent us using systems and equipment which are internationally renowned but are made in countries with them we are in cold war and there is a fear using their equipment in sensitive parts of railway industry. Political and security reasons is preferrable to technical quality.
Governmental Rules	Regulatory Barriers	Barriers/Limits	In particular, there is a legal gap in Iran, and we do not have relevant legal regulations and restrictions. I say it is not forbidden, although it is not legally approved. But there is always the risk of being outlawed.
Governmental Rules	Regulatory Barriers	Barriers/Limits	Since this is a new concept and has not been implemented vastly so far, I think there is not any regulatory or legal hurdle for that, but future wise we will certainly face some prohibitive laws and regulations.
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	This a the must have thing that we have to have to convince stakeholders and also definitely the training. That is part of convincing the stakeholders. We should bring them on the same page we are. ¶
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	One of them, maybe would be their knowledge about Blockchain
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	- Introduction of blockchain in the set of stakeholders¶- Full explanation of blockchain in the group of stakeholders
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	Introducing blockchain technology as fully as possible, holding training courses for experts and managers involved in the field of equipment supply
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	They need to know what specific problem(s) is going to be solved using blockchain and how the success made can be tracked or measured.
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	In general, they need to educate younger generations and guarantee the benefit of stakeholders. They also should lessen the fear of some companies which are more traditional. It should be clarified how it works, and how it could be beneficial. All these needs education and training.
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	Also building cultures and educate the companies.
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	The biggest is to teach them not to be afraid.
Training Stakeholders	Providing Infrastructures	Conv. STKHDs	education and culture building. We need to show stakeholders how it works and how it will be implement in industry and in everyday processes. We need to acquaint them with the ins and outs of this technology.
Facilitating Conditions and Its Use	Providing Infrastructures	Conv. STKHDs	Creating suitable infrastructure and facilitating its use

Compelling them to Employ the Platform	Obligation	Conv. STKHDs	We have techno-push and market-pull. Regarding Blockchain, we do not have any market-pull. Because the market is not familiar with it. If we introduce Blockchain and train the companies, this need could be created. But, in my idea, a big part of it should be techno-push. For example, a company like MAPNA can set a regulation for its supplier to work in Blockchain platform. We can push this technology because we have a large market share. If we do not force our suppliers to use this technology, there would not shape any Blockchain. Since the whole chain should cooperate in this platform, the one who is the biggest leader in this chain can push other companies towards using it.
Introducing Benefits	Benefits	Conv. STKHDs	Showing that this technology is going to improve us money wise. It is one time spending money and afterwards, we are picking and drawing some products from it
Introducing Benefits	Benefits	Conv. STKHDs	Having a plan. There is a term in this regard that I cannot recall. You are going to have the tradeoff plan showing that these are the benefits of implementing Blockchain.
Introducing Benefits	Benefits	Conv. STKHDs	. We should explain this technology elaborately and convince them that this technology in the long run could be very helpful. When you do smart contract management, it means the process is being done paperless. It could be beneficial for the nature and moneywise it is beneficial for them.
Introducing Benefits	Benefits	Conv. STKHDs	Somehow, it would be in stakeholder's benefits.
Introducing Benefits	Benefits	Conv. STKHDs	Stakeholders need to be told about how blockchain works and all its benefits.
Introducing Benefits	Benefits	Conv. STKHDs	we can introduce them to Blockchain's benefits.
Introducing Benefits	Benefits	Conv. STKHDs	The advantages of this technology should be defined in a way that introduces this technic as a reliable and beneficial approach.
Introducing Benefits	Benefits	Conv. STKHDs	we should first describe that using such a chain is a great advantage for themselves. For example, a contractor provides one of our projects with a control cabinet that consists of so many components. If an error occurs in this cabinet, the contractor can determine the cause of the problem himself by tracing back the components and producers within the chain. The component causing such problems can be detected.
Practical Examples	Benefits	Conv. STKHDs	Providing practical examples to introduce the advantages of using blockchain
Practical Examples	Benefits	Conv. STKHDs	Since it is a big change, they can be told that there is no need to shift the whole supply chain platform to a blockchain. We can start with a single feature used for tracking delivery. Once the results are visible to stakeholders, they may decide to expand using other blockchain features.
Practical Examples	Benefits	Conv. STKHDs	We need to stablish a case in a small scale and the benefits becomes clear.
Practical Examples	Benefits	Conv. STKHDs	The most important requirement is building the infrastructure and try to build an accepted culture.