Intelligent transformation of Logistics hub with automated transportation by integrating Blockchain Technology

Graduation committee
First Supervisor: Dr. Ron Van Duin
Second Supervisor/ Chairperson: Dr. Wijnand Veeneman
External supervisor (Port of Twente): Sebastian Piest

TU Delft

Suraj Dharmasastha (5032571)
MSc Management of Technology

Intelligent transformation of Logistics hub with automated transportation by integrating Blockchain Technology

Master thesis submitted to Delft University of Technology in partial fulfilment

of the requirements for the degree of

Master of Science in **Management of Technology**

Faculty of Technology, Policy and Management

by

Suraj Dharmasastha

Student number: 5032571

To be defended in public on August 30th 2021

Graduation committee
First Supervisor: Dr. Ron Van Duin
Second Supervisor/ Chairperson: Dr. Wijnand Veeneman
External supervisor (Port of Twente): Sebastian Piest

TU Delft

Acknowledgements

Before you is the thesis" Intelligent transformation of Logistics hub with automated transportation by integrating Blockchain Technology". This study concludes my Master's degree in Management of Technology at the Delft University of Technology.

I'd want to start by thanking my first supervisor, Prof. Ron Van Duin, for his unwavering support and trust throughout the entire process. Your informative remarks on my work are much appreciated, and I am grateful to you for introducing me to various experts in the field of both supply chain and Logistics. Second, I'd like to express my gratitude to Sebastian Piest, my external supervisor from the Port of Twente, for guiding me throughout the project, arranging visits to the port terminal, and presenting me to the authorities and representatives of the consortium, especially during COVID times. Last but not least, I'd like to express my gratitude to Prof. Wijnand Veeneman, my second supervisor and chair, who provided me with new insights by looking at my work from a different perspective. His suggestions helped me fine-tune the details of my work. In addition, the online presentations and conversations with my committee members aided me in sharpening my thoughts and elevating the quality of my work. Without the excellent advice and assistance of my supervisors, my thesis would not have been possible.

I acknowledge my gratitude to all of my loved ones, particularly my close friends and family, who have kept me sharp and grounded. The learning experience has not been the same after the extraordinary COVID-19 epidemic. Thank you to the TPM community and all of my TU Delft friends for sticking with me through what might have been an emotionally draining period and for being a supporter. Finally, to my parents, thank you very much for the limitless love and advice you provide me with throughout my journey.

Executive Summary

The port terminal logistics is foreseen to undergo a significant transformation as a part of the emerging industry 4.0 revolution over the coming years, where issues like transparency and trust are to be considered. Combi Terminal Twente at XL Business park is considering a variety of innovative systems to improve efficiency and long-term viability for diverse functions. Moreover, large enterprises with a global reputation use the terminal's services, boosting transportation demand, and, as a result, the terminal's infrastructure is expected to improve in the following years.

The terminal operations comprise various complex processes requiring different mediators resulting in high transaction costs. Moreover, the processes still include manual paperwork, which results in inefficiencies and quality degradation, and data error reduction is considered to be the highest-rated automated improvement in business processes. The present system is only capable of receiving or sending data, making it a one-way information system. The terminal operators claim that the change in planning is critical and cannot be done quickly. The unavailability of a secure communication mechanism demonstrates a lack of coordination among the actors. Meanwhile, Blockchain technology can create transparency through decentralized ownership that monitors the flow of products from the point of origin to the end customer, allowing for continuous supply chain monitoring. Moreover, smart contracts can be used to verify the validity of documents by removing the need for complicated paperwork. Because each of the actors has a copy of the ledger, information about any transaction is distributed among them.

According to the literature study, blockchain integration in business processes is currently under-researched, while research on supply chain inter-organizational business processes is limited. The research paper intends to fill this scientific gap by creating the business process of terminal operations so that the current and the improved blockchain integrated processes can be compared. It addresses the inefficiencies and the bottlenecks of the current process so that blockchain use case solutions specific to those problems can be accommodated. The research is carried out in various stages, including problem identification, suggestion, development, validation and finally, the conclusion.

The analysis started with an extensive description of the terminal's process, which was chosen as the case study for the research. Because the firm manages the transportation activities, the Combi Terminal Twente (CTT) is used as the unit of analysis. This has aided in gaining a better knowledge of transportation activities and evaluating the technology's application for hub-to-hub logistic operations. Also, to understand the intensity of changes that could be bought into the system when a disruptive technology like blockchain is implemented, different levels of digitalization is studied. The study also emphasizes identifying enabling technologies that can enhance the functions of blockchain applications and implementing automation had in hand. Four enabling technologies are determined in the research; IoT, the Physical Internet, Artificial intelligence and cloud computing. Furthermore, it was feasible to identify the significant

drivers of process delays and bottlenecks by analysing current physical and information flows at the terminal. The process identified is illustrated using Business Process Model and Notation(BPMN), a graphical notation that all business users in the process can understand. The business analyst who produces the original draft of the process, the technical developer who implements the technology that will conduct those processes and the business people who manage and oversee those processes can all be considered users.

During the course of analysis, six main areas were identified where blockchain technology can be employed; secured communication to secure release reference number, container sorting, planning routes and congestion, trade documentation, certification & maintenance of the assets, and finally fleet management. All the identified processes require an improvement in information sharing and enhanced information accuracy and swiftness. For each issue, blockchain solutions are determined and were validated through interviews. The real-time feasibility and challenges associated with those solutions were also attained by interviewing blockchain developers and logistics experts. Furthermore, to identify the impact of the technology on terminal operations, some process KPIs are defined and a framework is designed to validate them. The framework is categorized into operational, informational, financial and environmental on the Y-axis and the identified solutions of blockchain on the X-axis.

The interviewees unanimously accepted the importance of process visibility on the total process performance, and the value blockchain technology could provide. The respondent suggested the first solution (elimination of release ref number duplication) could be used more of an additional registration or a security layer in this particular situation, rather than entirely relying on it since the terminal has already implemented an OCR system. However, blockchain developers are already working on similar solutions for securing container release by assigning tokens. According to the respondents, the second solution (container sorting) could be carried out without the application of blockchain. But, If there is any case of damage and the information or the report related to it has to be shared with the respective stakeholders, the solution could be of better use. In the third use case, the respondents forecast the availability of unified data provided by blockchain technology to ensure access to documents in real-time. Also, the most prominent development and Proof of Concepts the experts working on are digitalizing documentation. Therefore, this solution could be considered as a starting point for implementing the technology.

The fourth solution for identifying congestion and routes, the logistic expert suggested that the application would only be helpful if organized at a park level. The blockchain developers also pointed out the large amount of data produced from VANET and the difficulty in storing such a vast amount of data in smart contracts in this case. Moreover, they added, it is also important to convince all the current stakeholders to join the initiative to make this work. For the fifth solution (certification and maintenance), using digital twining technology and NFT (Non-fungible tokens) to store all the data related to the assets could make it work in real-time circumstances. The spare parts also can be ordered from a credible vendor based on its service history stored in the smart contract. For the sixth solution, the interviewees had a similar perspective as the previous one. However, including the events such as accidents to be

registered in the system during the fleet operations will help the Terminal operators market themselves by building a transparent system. Furthermore, alternative solutions were studied to critically evaluate the success factor of blockchain technology to select the most suitable solutions to be implemented. Finally a subjective evaluation of the impact of the applications on the KPIs was also carried out, and the most significant indicators were determined in each category.

In conclusion, the research contribution is as following; First, from a practical point of view, analysis facilitated the recognition of bottlenecks in the current inter-organizational processes, where the unloading process is studied and depicted in the report. Second, the proposed categorization of blockchain solutions may help understand the different uses of blockchain in Port terminal operations. Third, from a Business Process Management point of view, the improved business process extends the knowledge in BPMN, and the domain of blockchain-based information systems and the findings are validated through interviewing experts. The alternative solutions were considered to crucially evaluate the technologies success rate. Also, the significance of the applications on the KPI's specific to terminal operations is investigated. Finally, based on the findings and the interview, a roadmap for future implementation is determined to develop proof-of-concept leveraging opportunities offered by blockchain in the future.

Table of Contents

1.Introduction

One of the most talked-about emerging technology is Blockchain with its numerous applications over many industries. However, its application has not been used much in the fragmented and sometimes extravagant logistics industries. Diffusion of blockchain technology in logistics and transportation could have a massive impact and the application of this technology could solve numerous problems resulting from complex functionalities which involve many players and actors. This includes a large number of contracts, tracking, payments and communications (Weber, 2016). Blockchain could be one such technology that could help to connect many players and handoffs within the regime bringing efficiency to the many detached elements. Blockchain in logistics could bring transparency throughout the lifetime of the shipment as it can be used as a distributed ledger. Perhaps, these data are not subjected to changes and are decentralized and hence the technology creates more trust and security leading to a pathway of information which is transparent from shipments origin to its destination (Tijan, 2019). Furthermore, it is unlikely a system gets disrupted due to a failure or a localized attack when it is decentralized. This will result in lower transactional cost, quicker processes and reliable data exchange within the industry. However, for this to happen, a set of standards which are unified across borders and industry is needed.

Over the next several years we will likely see the adoption of blockchain and its application in logistics and transportation. There are multiple companies testing various blockchain solution to solve issues ranging from data processing to fleet management. The logistic industry just recently took the interest in technology. Several blockchain solutions for logistics are already entering the market. For instance, In March 2017, IBM and Maersk, the Danish shipping giant started a joint-developed project to create a blockchain platform for cargo information storing (worldmaritimenews.com, 2017). Dramatic transformation can happen in the global logistics and transport sector due to the rise in new digital technologies. The different part of the world is connected through the flow of goods, service and data with dynamic market structure changing customer expectation and emerging competitive business models. The application of blockchain has great potential in the logistics industry especially in transportation as a huge number of actors and a considerable number of transactions is associated with the supply chain. However, the extent to which these transactions can be digitalized has been low and the documentation typically depends on paperwork (Merkas, 2018). Furthermore, to cope up with the customer expectation and to build a satisfying customer base, the industry has to invest in traceability of the goods so that the customers receive all the information starting from its origin.

Intelligent transport systems for logistics have been influenced by the rapid development of modern technologies and thus has displayed high degree of social complexity and leaving many unsolved problems. Such problems occur due to security risks which are associated with centralization bias and lack of mutual trust among the users of this technology. Moreover, a hindrance in a smooth flow of goods and money occur when there are no trusted intermediaries. (Yuan, 2016). The companies need to do more than just keeping the track of products leaving

the production unit or the arrival at the warehouse in this advanced technological phase. It is necessary for the companies to know what is happening in the real-time, to make sure the products are exactly at the defined stage of the developing global supply chain.

The logistics service provider needs to give access to the information system and there is lack of direct access at the intra- organization level since the process centralized. However, the blockchain has the potential to provide a decentralized platform and allows third parties to access the information related to the process involved in logistics without the approval of the logistics service provider (Merkas, 2018). Intelligent transportation could be considered as one of the novel technologies which is planned to be deployed all over Europe that has the potential to be a game changer for logistics and transportation in terms of sustainability, safety and cost. However, its deployment depends on the penetration of the technology, adaptation of regulations, agreeableness of various logistics sector and most importantly collaboration of various stakeholders. Furthermore, according to statistics published by European Commission majority of road accidents are due to human error and 60% of it could have been avoided if the driver would have informed about the condition in prior (European Commission, 2016). The autonomous trucking system or the truck platooning technology has a huge potential for disruption. Making autonomous trucks in Logistic operations could be a breakthrough by reducing the effects of CO2 emission and increasing overall efficiency and avoid pull over due to regulations along its pathways. Considering all the benefits of technology, the thesis will focus on exploring the potential of using the application of blockchain for enhancing the logistics and intelligent transportation making it more transparent and sustainable compared to the conventional approach.

1.1 Research Background

Logistics partners aligned together to form a project called **STEERS** (Towards intelligent inter hub logistics) that combines Combi Terminal Twente, Bolk Transport, Distribute, the University of Twente and the Hogeschool Arnhem en Nijmegen, as well as branch partners (Port of Twente, XL Businesspark Almelo) and the Regio Twente to explore the real-life challenges associated with the logistics operation in hub-to-hub logistics and to investigate the potential of intelligent and connected technology to address such challenges. The main motive of project STEER is to investigate the requirements for the application of automated vehicles in ‘business park transport’ and simultaneously explores the potential of intelligent hub-to-hub transport. This thesis aligns with the interest of project STEERS and intends to investigate the relevance of blockchain technology in enhancing intelligent inter- hub corridors and concurrently explore the potential of the technology in implementing automated vehicle in inter hub transportation.

The STEERS project has been broken down into different work packages. The first work package is to explore the real-life challenges associated with the small to medium size logistics hub and how intelligent and connected technology solutions can address these challenges in a

drive to achieve industry 4.0 technologies. The second work package is the feasibility analysis, to divide the challenges into clusters and a state-of-the-art review for feasible combinations of technologies to address the needs and interactions and define the KPI's per cluster. The third work package is the preliminary proof-of-concept, where a simulation is created to test different logistical concepts. Work package four is the dissemination, to discuss the results of the first three work packages, and the preparation for a four-year RAAK PRO project.

Figure 1.1 Illustration of XL Business park and major hubs at Almelo

The focus of this thesis is to introduce the application of blockchain to address the challenges identified for the first two packages of the STEERS project. The research aims to investigate the interactions between different processes (such as communication, planning, and transportation) and associated challenges at a small-to-medium size logistics hub. Combi terminal Twente (CTT), situated at XL Business Park (Fig 1.1) is an ideal representative of such a small-to-medium size logistics hub, which includes Bolk Container Transport. They transport goods to multiple warehouses such as Bleckmann, Timberland, V-Tech and Madison in the proximity situated at the park. The physical infrastructure of XL Business park will provide a real-life setting to investigate and further explore the potential of this project.

1.2. Research scope

The logistics sector is considered to be a substantial part of the Dutch economy. According to Statistics Netherlands (2016), the sector contributes 62 billion euro (more than 10% of the GDP) to the Dutch economy. Since 2008, the government has been aiming to make the Netherlands the European market leader in the control of international goods flows.

(Commissie Van Laarhoven, 2008). According to Van Geffen et al. (2017), the logistics sector is growing to this day and the demand for expanding existing distribution centers/ hubs and automating the process at new locations has become extensive.

Port of Twente connects transporters and companies with the most dynamic main ports in the east of the Netherlands. The transportation and logistics sector of Port of Twente are mainly intermodal and are partnered with five municipalities (Almelo, Enschede, Hengelo, Hof van Twente and Lochem). With the highly innovative Container Terminal (CTT), the Port of Twente is the biggest inland port of the Netherlands. **Combi Terminal Twente (CTT)** is a modern inland terminal in Hengelo situated at **XL Business park**, with its own storage and transshipment terminals in Rotterdam, Almelo and Bad Bentheim. The CTT offer Synchromodal transport with the possibilities of water, freight rail and container transport by road.

As part of expanding the scope of the terminal situated at Almelo, developments at CTT are still going on at a high pace and with great expectation. The authority at CTT is looking at various advanced systems to enhance efficiency and sustainability for various functionalities. Large companies with international reputation use the facilities at the terminal increasing the demand for transportation and therefore the terminal's infrastructure will be improving in the next few years. As a result, more automated systems are to be implemented in the facilities to enhance efficiency. Automated terminal trucking system for hub-to-hub logistics is one of the major objectives of CTT to achieve in the coming years to remain sustainable and have a competitive advantage over other terminals.

1.3. Problem Introduction

According to the literature on information related issues in hub-to-hub logistics, it is found that multiple data sources exist but no coordinated hub providing the information in a standardized and uniform way is available. In effect, the data is scattered over multiple servers in wildly different formats and with varying strengths and quality. All terminals face continuously new challenges in meeting transport growth rates while the capacity of infrastructure stagnates (Castelein et al. 2019). Loads such as containers, break bulk or liquid bulk cargo are always relying on road transport as a part of their supply chain. In this context, road freight transport is an important player in the logistics chain that cannot be completely substituted for. Tools that lean on existing technology are needed in developing tools that optimize this part of the logistics chain. With regard to information access or information communication, the present focus falls on the following issues:

- Lack of communication and data sharing between stakeholders.
- Lack of predictability of the traffic situation (Böse 2017).
- Trucks arrival time is not always known.
- Difficulty to consider mixed traffic condition into account during the planning phase.

- Lack of cross-process communication and coordination among the logistics chain (Rushton et al. 2014).
- Requirement of decentralized information sharing for efficient truck planning.
- High delay and handling time at the terminal.
- Inefficient gate operations.
- Access to data only from designated location via on premise local system.

The thesis aims at finding solutions to problems arising during the transformation phase towards an automated transportation system with the application of blockchain. However, It is difficult to find a clear definition of blockchain in the current literature due to its presence in several applications and diverse functionalities. However, the broad spectrum of the blockchain solution includes public and private, anonymous or based on the user's reputation with a validation mechanism that can be centralized or decentralized. The uncertainty of the technology generates a lack of understanding and confidence in the logistics operator to try out its real benefits. Lack of research in the application of blockchain for the field of logistics and autonomous trucking could be considered as a scientific problem where no explicit solutions are yet available.

The current inter-hub information system will be studied to get a deeper understanding of the storage, transformation and transmission of information across hubs. Based on this, the application of decentralized technology like blockchain use case could be validated for the introduction of automated truck for hub-to-hub logistics. The technology has the potential to transform the existing system or the processes while giving new business opportunities and development possibilities.

This thesis aims to fulfil the theoretical and practical research gap on Blockchain potential on introducing automated trucking for hub-to-hub logistics. The research intends to present an in-depth evaluation of blockchain technology along with the real-time market application for automating hub-to hub transportation by interpreting the challenges associated with it. Furthermore, the research will also determine the potential of the technology in optimizing the information and physical flows by identifying the current inter-hub information system.

1.4. Research objective

The impact of the blockchain technology for automating hub-to-hub logistics is determined by identifying the contribution of the technology on the operations performed at the hub and evaluating them to get an optimum outcome. Perhaps, to understand the technological impact, the research also include the objective of identifying business case solutions where the blockchain technology could be implemented in the operation of automated transport for hub-to-hub logistics at CTT and the impact of these business cases are studied.

1.4.1 Research questions

The main research question formulated based on the objective is as follows:

MQ. To what extent blockchain technology could influence the implementation of automated transportation and inter hub logistic operation at XL Business park?

The sub-questions are formed to contribute to answering the main research question and from the research objective the following questions can be drawn:

SQ.1. What are the key operations in hub-to-hub logistics for implementing an automated transportation system?

The first sub-question address the features of blockchain technology based on available literature, interviews and onsite visit to the terminal. The analysis is performed in various aspect based on the application of the technology and based on the current process the bottlenecks are determined. The first sub-question will give a better understanding of the technology based on which the data for the second sub-questions is determined.

SQ.2. Which Blockchain applications and enabling technologies are needed to achieve automation in hub-to-hub logistics?

In the second sub-question, the key application of blockchain along with enabling technologies for enhancing automated transportation at the hub facility are determined. The applications will be determined based on the functionality which will be identified during the transport operation at the hub and can be classified as different business case of the technology for hub-to-hub transportation.

SQ.3. What are the key performance indicators of the container terminal to evaluate the applications of blockchain technology in automated transportation?

A list of key performance indicators (KPI) will be determined from the existing literature and each business cases identified in the previous sub-question will be evaluated.

SQ. 4. What is the impact on the Operational, information, environmental and financial flow of the logistics hub if the blockchain use cases are implemented?

The previous sub-questions will give a better understanding of the application of blockchain technology in hub-to-hub automated transportation while the final sub-question can address the impact of the business cases determined at Combi terminal Twente (CTT). The process starting from the loading of the truck at the hub and the operational flow till the delivery at the succeeding hub is studied to determine the impact. A business process modelling (BPMN) depicted in Fig 4.3 and 5.3 will help to better understand the impact of the use cases.

1.5. Research Methods

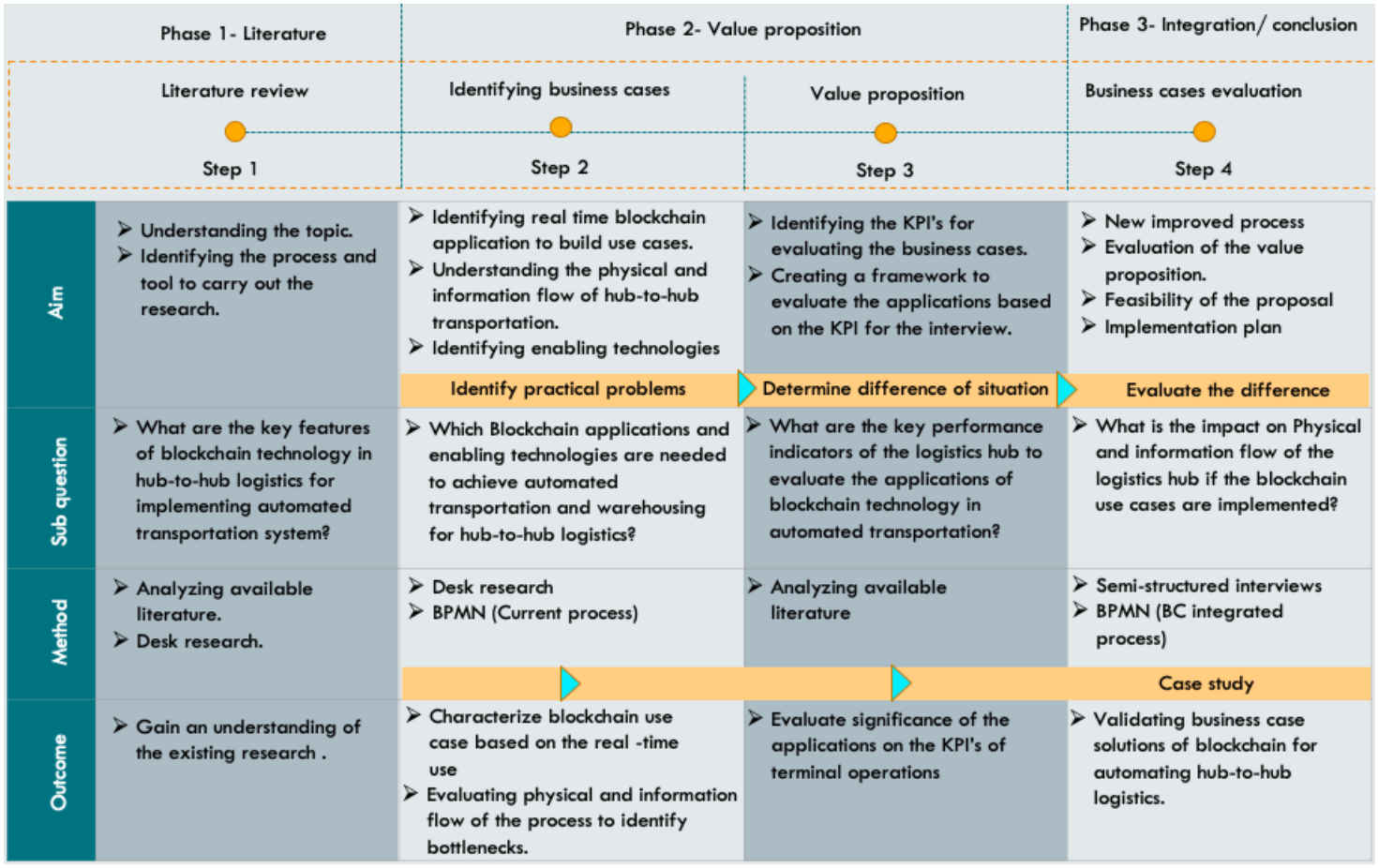


Figure 1.2 : Methodologies used in the research

For this research, an exploratory and a qualitative case study method with a deductive orientation is applied. This means that the theory and research questions are formulated before the data is collected and both primary and secondary data will be used for the research. This section provides a brief description of the approach used in this research project and Fig 1.2 shows all the methodologies included inorder to carry out the research. The data is collected in 4 stages, i.e. in SQ1, SQ2, SQ3 & SQ4 and the subsequent sub-questions will give an idea or an understanding to modify the previous questions. An in-depth understanding of the problem associated with the transformation of CTT to a smart hub with automated transportation is determined through this exploratory study. The narrowing down of the scope to automation of CTT gave a deeper comprehension of the physical and informational flow based on which the application of blockchain to overcome the bottlenecks associated with the process is evaluated. The difference of situation is studied using the expertise of the interviewees after identifying the practical problems and the research is conducted in an Action research method. An interactive inquiry process has been held to identify solutions to practical problem in a collaborative context. The main elements of action research are as follows:

- Identify a problem

- Research the problem and its probable causes
- Develop a response to the problem
- Implement the proposed solution
- Observe the implementation of the solution.
- Reflect on the results.

1.5.1 Research Phases

1.5.1.1. Literature (Phase 1): An in-depth literature review is conducted to understand the concept of the hub to hub logistics and the inter-organisational information system based on which the process and the information flow is studied. Furthermore, the key features and concepts related to blockchain technology are reviewed. This approach gave an understanding of the existing research and help in identifying the gap in the research. Figure 1.3 illustrate all the methods used in phase 1

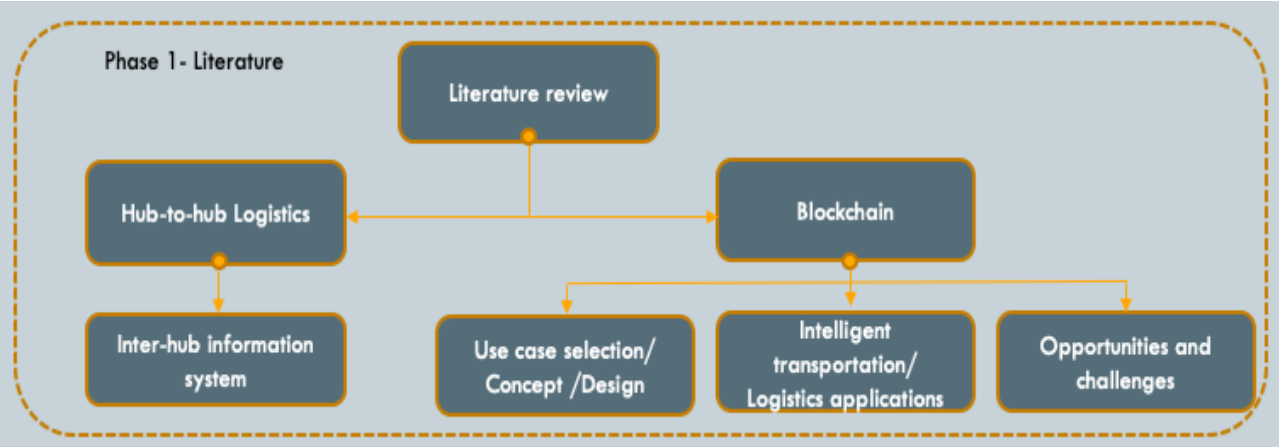


Figure 1.3 : Schematic representation of Phase 1

1.5.1.2. Value proposition (Phase 2) : The research aims at identifying real-time application available that will be used as a base to build the business case which is carried out with a desk research method. However, alongside the desk research, the process and the information flow at the hub is studied by visiting the site (Combi Terminal Twente) and by approaching the officials and the actors responsible for the operations. The the current process flow is represented graphically using BPMN (fig.4.3) after understanding the process flow. Furthermore, the evaluation of the functionalities offered by the current blockchain applications is structured to study the value the technology can provide. The current applications of blockchain is determined from various sources and search engines.. A categorization based on the value provided by the different applications will be proposed based on the research. Identifying the application of the technology has further helped in characterizing and developing use cases based on real-time use. Moreover, the business cases is evaluated by identifying the KPI's and this is carried out by reviewing available literature with a case study approach. A framework is created based on the findings to evaluate the application of the technology with respect to the KPI's and this framework is also validated during the interview in Phase 3. All the methods involved in phase 2 is depicted in Fig 1.4.

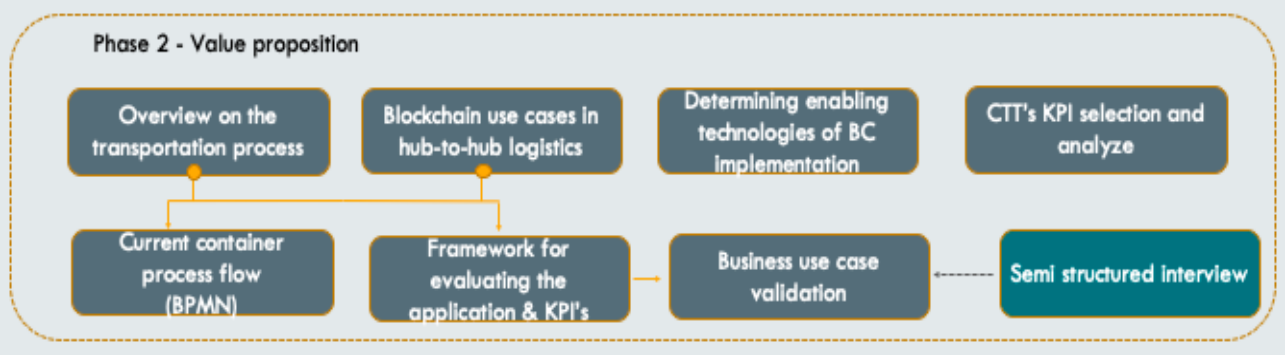


Figure 1.4 : Schematic representation of Phase 2

1.5.1.3. Integration/ Discussion (Phase 3) : Set of indicators identified can be used to assess the potential of blockchain technology in an automated hub to hub transportation. According to Garud et al, 2013. it is difficult to give an accurate conclusion whether the technology will succeed or become a new business model during the research phase. Indeed, an exploratory research approach could offer a set of possibilities or alternatives which could be considered during the future development phase. However, after understanding the application of the technology, the improved transportation process with blockchain technology is represented graphically using BPMN technique which is compared with the process identified in Phase 2. Furthermore, the difference of the situation is studied and validated through interview with expertise. The value propositions and the feasibility of implementing the applications will be evaluated through semi structured interviews along with an implementation plan. The figure below (Fig 1.5) illustrates all the above mentioned methodologies.

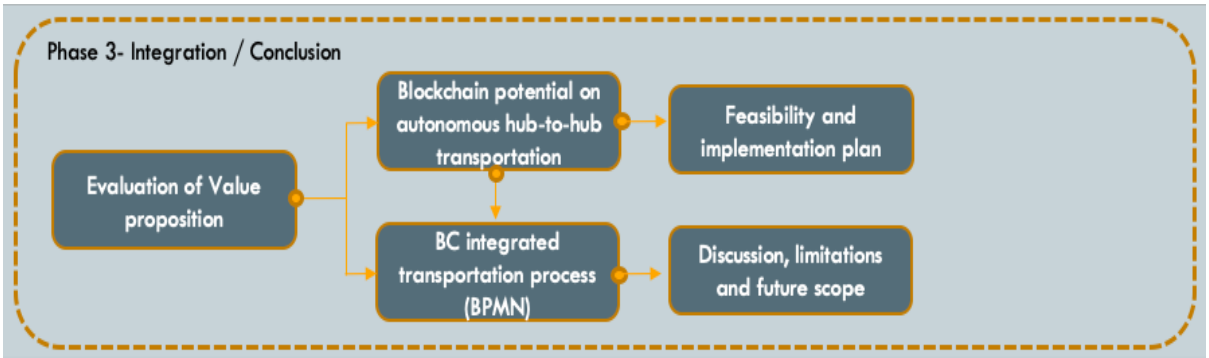


Figure 1.51 : Schematic representation of Phase 3

1.5.2. Methods

1.5.2.1. Desk research

The research is carried out to gather necessary secondary data (data that has already been published) and other information for completing the planning of the research. The information and data thus collected through desk research were then used for planning the research.

1.5.2.2. Semi-structured interviews

These are types of interviews that are performed for observational purposes, similar to unstructured interviews (Saunders et al., 2015). The study has a clear theme and list of

questions planned for the subjects, but the order of the questions could be repeated based on the nature of the discussion (Saunders et al., 2015). Besides, this interview approach is of benefit to small-scale research (Drever, 2003). This method of interviews also gives the subjects a degree of freedom to express their opinions (Drever, 2003). As already established, this research is a master thesis project with a six-month time constraint.

1.5.2.3. BPMN

According to Remco et al, 2008, the primary goal of the BPMN effort is to provide a notation that is readily understandable by all business users, from the business analysts who create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and, furthermore, to the business people who will manage and monitor those processes. Thus, BPMN creates a standardized bridge for the gap between the business process design and process implementation.

1.5.2.4. Case study

The main methodology used in this research is a qualitative case study and the techniques used in the research method is adopted from Yin (2009). The Combi Terminal Twente (CTT) is considered as the unit of analysis since the transportation activities are managed by the company. Considering CTT as the Unit of analysis has helped to attain an understanding of the transportation activities and the perspective to evaluate the technology's implementation at the hub. The process included in terminal truck transportation within the XL business park situated at Almelo is considered to evaluate the blockchain technology impact for hub-to-hub logistics. Furthermore, the case study is based on the process and the information flow during the operation. The evaluation of the process is carried out with the terminal truck leaving from CTT to Timberland. Forty containers are transported a day from CTT to Timberland and it is done with a single truck. This particular scenario has the potential for interjecting autonomous transportation in the operation. The actors involved in the process are identified and the information exchange among these actors is analysed to evaluate whether blockchain can play a role in introducing autonomous transportation between the two hubs.

2. Literature review

2.1 Selection Criteria and search Description

To find relevant sources, *Scopus* and *Google scholar* has been used for the literature review. The most common approach found in the literature regarding the concept were case studies, framework proposals and conceptual ideas. Search starting from a broad aspect of blockchain and its application in transportation and Supply chain to the specific application to implement it in real-time has been carried out. The search was narrowed down to "Blockchain" AND "Logistics", "Supply chain" AND "Smart Contracts", "Etherium AND ("IoV" OR "Smart Transportation" OR "Logistics"), "VANET" AND ("Blockchain" OR "Logisitics" OR "Smart Contracts" OR "Etherium"). The term "distributed ledger" or "decentralized ledger" was also considered for blockchain technology during the selection process. A quick survey of the results was done to understand the major future aspects of IoV specifically in the logistics industry and the areas where blockchain could be integrated. Further, technologies that dealt with supply chain management which included procurement, inventory and other activities which were not related to transportation were ignored. The remaining papers were used to analyse and understand the concept, method employed, challenges and opportunities.

The search term was combined in one search query and therefore the results came up with no duplication and were made up of matches in the keywords, abstract and title. Furthermore, a total of 248 results were found and from which relevant pieces of literature were selected. The searching process focused on papers published after 2015 and written in English and no focus on modalities other than road transportation were considered applicable for Logistics management.

The research field can be considered young since the first document related to blockchain and transportation date from 2016. Thereafter a significant amount of publications has been made and this shows the increasing interest in the application of blockchain in transportation purposes. However, the integration of smart transportation in logistics using blockchain technology has been overlooked much. The publications after 2017 found to be relevant to the topic which has been looked upon and the articles before that were not related to the interest of the selected topic. Therefore a preceding examination of some of the papers selected manually was not directly related to the topic and showed the need for criteria of exclusion. Some papers did not address the blockchain in particular even though they mentioned transformative capacity of blockchain and other emerging technologies and therefore these papers were excluded.

2.2 Findings

2.2.1 Hub-to-hub logistics

The supply chain consists largely of the transport of freight, often using different modalities as ship, train, and trucks. Therefore, freight needs to be transported between the different modalities within the supply chain, from container terminal to distribution centres, or from airports to logistics service providers. We define this kind of transportation as hub-to-hub transportation. A hub is also called a logistics hub and Huber et al (2015) defines these as linking points – infrastructure facilities and nodal points – in logistics networks. Figure 2.1 represents processes carried out to transport goods from one hub to another. These hubs serve primarily as transhipment points for flows of goods. **A** logistics hub is a centre or specific area designated to deal with activities related to transportation, organization, separation, coordination, and distribution of goods for national and international transit, on a commercial basis by various operators (Pienaar, 2008). Hub-to-hub logistics, when not efficiently executed, can cause a lot of delay. Janic et al (1999) defines this delay as Terminal Time, the time between two different transport activities. Besides moving freight between two transport modalities, hub-to-hub logistics can also be routine work, daily transport between two hubs. Therefore, it is useful to investigate how hub-to-hub can be automated, to reduce daily costs and to make more efficient use of available transport.

Figure 2.1 : Hub-to-hub logistics process (not to scale; illustrative only)

2.2.2 Inter-hub information access system and challenges

Information technology plays a major role in the supply chain which enables a greater degree of coupling or integration between the trading parties. As the business environment grows more

competitive and introduces more global pressures, organisations are constrained to create and sustain a competitive edge. Information technology has enabled the tracking and tracing of the products throughout the operation. Subramani et al, 2004, differentiated two perspectives of information technology; exploitation (improving operational efficiency) and exploration (discovering new possibilities). However, the Inter-hub information system could be employed to explore new possibilities since most of the applications of hub logistics focus on the perspective of exploitation. It is important to explore more of its application to discover new opportunities while exploiting the information system to smoothen the physical flow (Baalen et al., 2008).

Barrett and Konyuski used the term "Inter organisation information system" in 1982 to define the inter/ intra connection between two or more different organisation for billing and payment practices in supply chain operations (Barrett et al. 1982). However, after few years this system was described as an automated information system by different organisations (Barret et al. 1982). Furthermore, Johnston et al. 1988, extended this concept as an IOS built around information technology that facilitates the storage, transformation transmission and creation of information. The "Internetwork operation system" differs from an internally distributed information system as it allows information sharing across different organisations. Therefore this system will enable vertically integrated hierarchies by efficiently building cooperation among the actors involved in the network (Wilson et al. 1998)

According to Casteein et al., 2019, new challenges arises in meeting transport growth rates while the capacity of infrastructure stagnates and this is a major concern, especially for road freight transportation. Available literature encourages enhancing operations visibility of transportation-related stakeholders could be a proposal to tackle down this issue (Woo et al. 2013). Furthermore, according to Woo et al, 2013, in-creased information sharing between the port and supply chain actors contributes to reducing order cycle times, cutting inventories and achieving more flexible systems. Haralambides et al, 2017 points out that improvements concerning information systems, among others, can be seen as the initial step towards reforming the transportation process without pursuing other fundamental changes (such as policy or organizational shifts).

2.2.3 Structure of Inter-hub information system

Srour et al, 2008, classifies the architecture of the structures used for sharing information among different hubs which are geographically diverse (Figure 2.2):

- **Bilateral**: This structure enables the sharing of information in one to one connections. Phone, fax and electronic data interchange are some of the examples which use a bilateral structure for exchanging information. this architecture enables the parties to design their message format during the transaction and it is simple to execute. Nevertheless, according to Baalen et al, 2008, this architecture lacks scalability because n(n-1)/2 connections are required to interconnect "n" parties.

- **Private hub**: The connections are established through the hub and therefore require fewer connections to connect every actor. The actors and the connections are equally proportionate ie, "n" parties signifies "n" connections. These are owned by a central body which connects the different actors to the external world with one or more structure.

- **Central orchestration hubs**: These type of information system do not belong to any of the parties of the network and they are distinguished by a many-to-many structure (Srour, 2008).

- **Modular distributed plug and play**: This architecture could be considered as a potentially disruptive one since this will help to connect with parties in the domain who are not known directly. However, they are not yet established completely, but developments are going on to implement them for various scope of work.

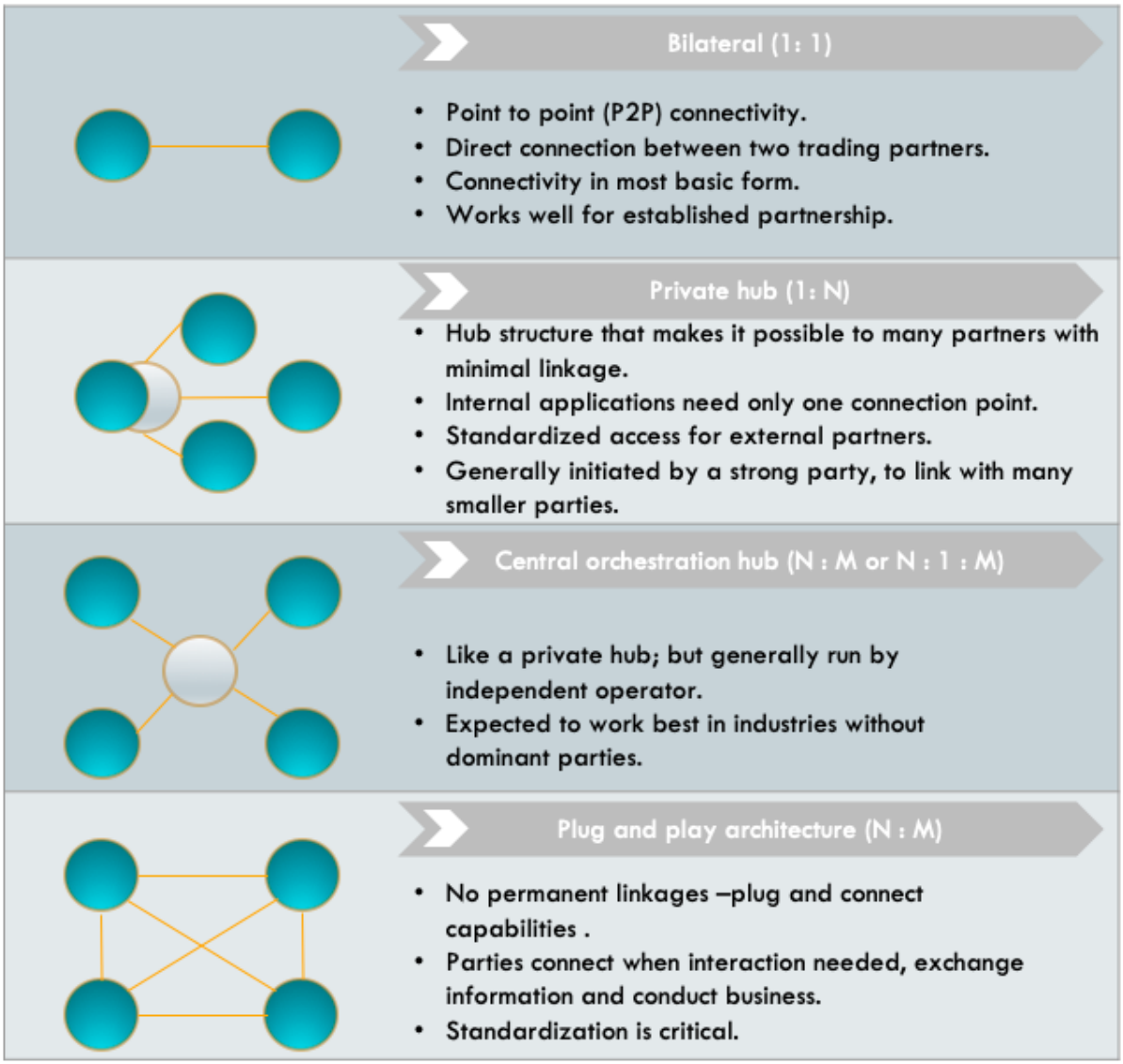


Figure 2.2 : Architecture of the structures for Inter-hub information system (Baalen, 2008)

The modular distributed plug and play represent the blockchain technology and implementation of such technology imply a shift from the architecture of the central Orchestration hub that is currently held by the Combi terminal twente (CTT). This shift not only has the potential to profoundly transform the current processes, but it also gives rise to a distinct set of possibilities and business opportunities.

2.2.4 Blockchain use case selection and design process

Blockchain is a technology of storing data that makes it difficult, if not impossible, to alter, hack, or defraud the system. Each block on the chain comprises a number of transactions, and each time a new transaction takes place on the blockchain, a record of that transaction is added to the ledger of each participant (Yang, 2019). Blockchain-based systems are developed in a step by step process and figure 2.3 represents a systematic design process which is inspired from the research of Jiang et al 2019. The whole procedure requires a clear understanding of business processes and compliance requirements of the use case to facilitate decision making.

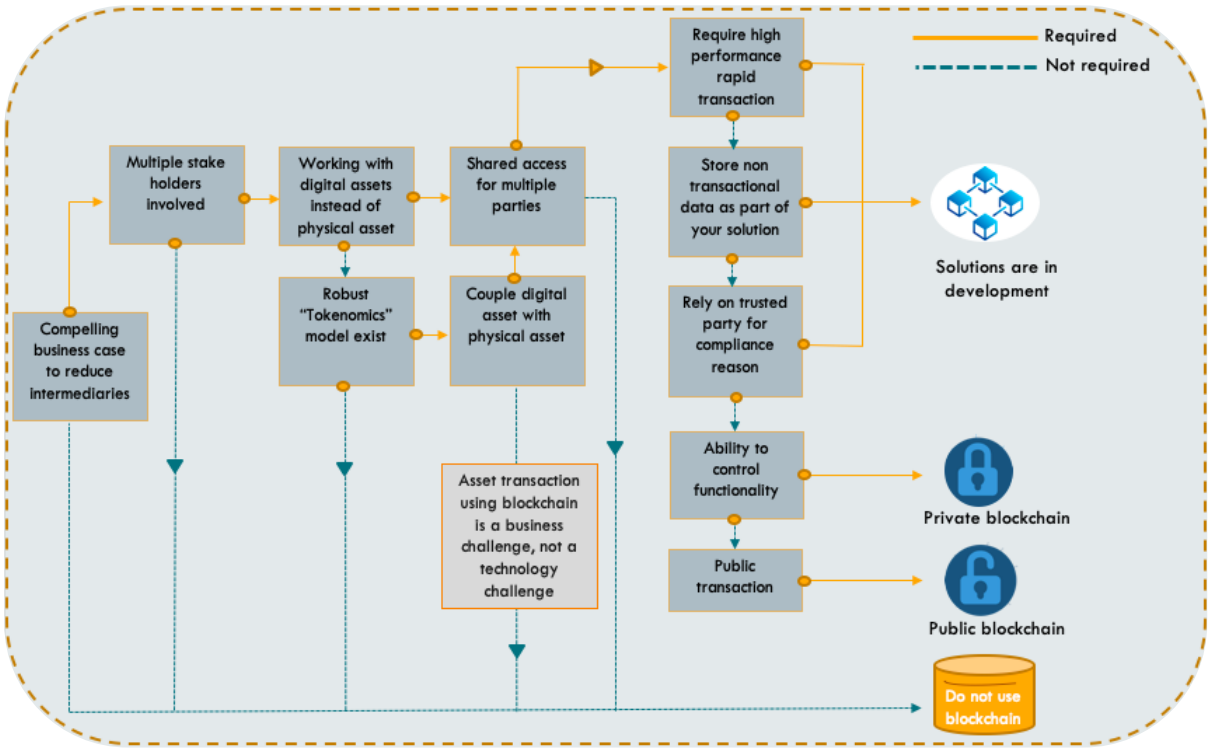


Figure 2.3 : Blockchain use case selection framework (inspired from Jiang, 2019)

The framework (Fig 2.3) presents following four possible outcomes based on criteria,

- Do not use blockchain
- Blockchain can't do this effectively yet solutions are in development
- Strong case for public blockchain
- Strong case for private blockchain

The procedure starts with a question on whether to decentralize trust (authority) – or not. A blockchain is more suitable where no single trusted authority is mandatory and the reliable authority can be distributed or partially distributed. If the trust authority can be distributed then rules and specifications regarding trust authority needs to be identified. Otherwise blockchain is not applicable and systems can be built using traditional databases. Given the restrictions of blockchains, critical concern is configuration of computation and data storage between on-chain and off-chain components. It all depends on business requirements and volume of transactions for a use case to decide about storage and computation infrastructure required for blockchain application. A thorough assessment of workload and capacity requirements needs to be done. Capacity planning is required to estimate storage and computation for a use case.

After that, a collection of design decisions around blockchain configuration need to be made, like the type of blockchain, consensus protocol, block size and frequency. The arrows only illustrate one of the possible sequences to make design decisions. Some decisions are required to set up acceptable levels of expansion (like block size and rate of occurrence), security, cost of processing and performance (Jiang, 2019)

Furthermore, selection of mechanisms for identity mapping of users and whether anonymity is required or not. Permissioned and Permission less blockchain may have different specifications regarding anonymity of participants. Finally the decision about deployment needs to be made and based on the needs of the use case and findings of capacity management blockchain can be deployed in house with multiple machines or on cloud if use case requires dynamic scalability.

2.2.5 Elements of Blockchain

Blockchain is a system having various components that work together to perform transactions of business operations. Each element in the blockchain has a specific role to play as listed below.

- Node: Node is a computing device within a blockchain that can initiate, receive or validate a transaction. A node operates with the help of a software application that offers various functionalities related to the business use case. Blockchain typically has two kinds of nodes i.e., validator nodes and member nodes. Validator nodes have more capabilities as compared to member nodes as they can initiate, receive and validate a transaction whereas member nodes can only initiate and receive a transaction.

- Transaction : Transaction in a blockchain is a collection of various data items that carries facts about the exchange of something like product, service, entity, event or anything that carries value. For example, it could be transfer of ownership, issue of certificate etc.

- Block : A Block is a data structure that keeps a set of transactions. Every block on successful verification is distributed to all nodes of the blockchain network. A block

contains various elements and a block number can be used for unique identification of blocks in a chain of blocks. Nonce is a random number that helps generate a hash code with reasonably difficult mathematical computation. Previous represents the hash code of the previous block and Hash represents hash code of current block.

- Chain: A chain in a Blockchain is an interconnected sequence of blocks in chronological order with the latest block in the last with each block having reference to its previous block to trace back the complete blockchain.

- Miners : A blockchain may have two kinds of nodes Miner nodes (also called Network nodes) and User Nodes. Miners are the one who have the copy of the blockchain and they also participate in the block verification process, whereas User nodes can only initiate a transaction.

2.2.5.1 Consensus Mechanism

Consensus algorithms are used to assure necessary conformity on a single state of the network consisting of distributed machines or network nodes in a blockchain system. The consensus is assessed by comparing the hash codes of all copies of the chain (Yang, 2019). This assessment involves mathematical problem solving that requires a lot of computing power. For this provision of reward is required for people to contribute resources for maintaining the network. Following are two popular consensus algorithms:

Proof of work (PoW) is a mechanism in which all the network nodes or participants on the network fetch recent transactions as a block. Each block within the chain must have hash code of the previous block (Yang, 2019). To select a network node who will be assigned to process the block, a reasonably complex mathematical problem is created. The node that solves the given mathematical problem first is allowed to process the block. For doing this job, the network node is rewarded that could be transaction fee. The complexity of the mathematical problem increases after every successful transaction i.e. the network node needs to compute larger hash codes. The complexity of the mathematical problem is also determined by the number of network nodes in the blockchain network.

Proof of stake (PoS) is a mechanism that requires network nodes to invest a native currency to perform a transaction i.e. users need to possess stake in the transaction (Yang, 2019). For example ether is the native currency in Ethereum blockchain, and a fraction of ether is invested by network nodes for processing of transactions and achieving consensus.

2.2.6 Blockchain application- Intelligent transportation

1. Increasing security standards & minimise malicious attacks.

Dorri et al. (2017), suggests a decentralized blockchain-based architecture for a smart vehicle ecosystem to enhance the security and protect the privacy of the user. The paper points out the

issues which make it necessary to implement such architecture. The concerns occurring due to the malicious attacks which can lead to the safety of the driver and also recognise the cases lead by the attack on the infotainment system which has the control on the core functions of the vehicle. Furthermore , the data exchanged between interconnected vehicles such as platoons can be sensitive and must make sure the user privacy is ensured. Moreover a centralised infrastructure could collapse when the number of users are too large and this failure could affect the entire network. The paper propose a block chain based architecture to protect the privacy and the security of users by illustrating wireless remote software updates and the changing insurance fees of the vehicle by qualitatively arguing the resilience of the architecture against common security attacks. However, there is no quantitative method been used to illustrate the implication and the practicalities of the methods in real-world scenario. Perhaps, the paper gives an overview of the application and advantages of blockchain over conventional methods which can be used in the vehicular system as a whole.

2. Increase trust and secure the exchange of money and information.

Yuvan et al. (2016) proposes an intelligent transportation system framework based on blockchain for ensuring profitability, stability and efficiency of the transportation system. The researcher acknowledges the trust issues among the actors leading to the complex information flow among them since money cannot be transferred from an entity to another without the existence of intermediaries. Also, the performance of smart transportation or even the availability of such technologies will be affected if it is centralised due to malicious attacks. The paper presents a case study for real time ride sharing services based on blockchain which is aimed at stimulating guidance for future research work in this new direction. However , the underlying rationale is not being explored to develop a new business model or even practical applications scenarios for blockchain based intelligent transportation system.

3. Improve key management schemes : Heterogenous intelligent system.

Lei et al. (2017), a framework for secure key management within a network which is heterogenous which includes a decentralised network topology and can be used to distribute and simplify management. Majorly two components are discussed and it includes dynamic transaction collection scheme and blockchain based key management scheme. Furthermore, the paper illustrates a system to reduce the transfer time of blockchain schemes by “Flexible transaction collection period selection method”. The paper depicts the importance of sending cryptographic materials to the Security Manager (SM) which in turn can be used to collect and manage main information related to the vehicle. The key role of the security managers include capturing the vehicle departure information, executing rekeying to vehicles within same security domain and encapsulating block to transport keys ((Lei, 2017) . It includes a set of analysis and simulations that could determine the efficiency of the framework by assigning a central manager and a dynamic scheme which allows the security manager in a flexible way to fix various levels of traffic.

4. Vehicular networks: Credibility between vehicles & incentives for sharing information.

Li et al. (2018), identifies the difficulties in forwarding reliable announcements to various users since the identity of the users is unknown. There is a lack of motivation among the users to forward the announcements primarily due to monetary and privacy reasons. The paper proposes a network enhancing privacy-preserving incentive announcement called *Credit coin* (Li, 2018). This incentive will motivate the user to share information regarding traffic. It also includes a set of experiments that shows the efficiency of credit coins in the practical simulation of intelligent transportation. However, the simulation doesn't show how they could be managed and the coin balance of the Credit Coins. This lead to an hypothesis of an effective credit coin can be more reliable for future research or not. Furthermore, on vehicular networks, Yang et al. (2019), describe a blockchain-based decentralised trust management system by employing a joint *Proof of work* (Pow) and *Proof of stake mechanism* (PoS) to evaluate the performance via simulation. The paper demonstrates the effectiveness, feasibility by including the calculations and storing trust values within the vehicular networks. The papers above mentioned recognises the importance of credibility of messages exchanged between vehicles, introducing incentives for drivers who are motivated to share information about traffic or unexpected events, such as car accidents

5. Vehicle Ad-Hoc network enhancement

Internet of things (IoT) has aided the advancement of Internet of Vehicles (IoV) and Intelligent Transportation system (ITS) and one of the indispensable systems to be considered is the *Vehicular ad-hoc Network* as a key player which could ensure communication within the system. For designing the same, a reliable system of a secure inter and intra network communication with the reliability of data and trust is necessary. VANET's with the conventional centralized system can no longer function effectively with the rising ITS system complexity which includes large data storage, information security and intelligent management (Jiang, 2018). However, these complexities could be tackled by the application of blockchain and for the same Lu et al.(2018), propose a trust management system for VANET with the application of blockchain which works on a reputation score mechanism based on historical interactions to determine the credibility of a vehicle. They also propose a revocation and authentication framework for implementing VANET using the application of blockchain to maintain privacy but fail to address the communication security.

Xiaodong et al. (2018) emphasise on the amount of data generated by VANETs in the research and expound the importance of *Mobile edge computing* (MEC) to balance the resource consumption in VANETS's which are blockchain-based. However, the computational overhead of blockchain could be reduced by implementing this solution but the introduction of Mobile edge computing does not make it decentralized. Furthermore, Lei et al. (2017) address the heterogeneous intelligent transport system (ITS) management with the help of blockchain. Although the system can provide robust vehicular communication security, the privacy of the vehicle is at stake as it cannot be protected and if revealed can put the user at a risk.

Nevertheless, By considering this privacy and the communication security issue, Javaid et al (2019), presented a paper which is based on *Physical Unclonable Function* (PUF) and blockchain called *DrivMan* for data sharing and trust Management in VANET with the help of Ethereum and two smart contracts. A unique crypto fingerprint is issued to the vehicles by using PUF and results in data provenance. Furthermore, the decentralized ledger system will establish a secure data sharing during the storage and the retrieval of data that will enforce the integrity of the process. But the practicality of this system is yet to be tested in real condition and if it succeeds, the VANET's could operate securely and reliably with both data integrity and provenance.

2.2.7 Logistics Traceability and management

Wu et al (2017), propose a framework that leverages communication among the actors, distributed database and the BC technology to deliver information regarding the tracking of the shipment. This is made possible by combining the *Private-public ledger architecture* which also consider privacy requirements whilst providing the required supply chain visibility to the trading partners for making the right decision. This framework can support providing information peer-to-peer and as a result, the supplier and the customer could enhance their scope of distribution. However, the research was conducted and tested in a laboratory environment due to limitations. There could emerge several difficulties when a large number of nodes are included in the network during its execution. Another area where improvement could be bought in this scope is by increasing the number of monitors which in turn enhance the trust level as it is important to understand the trust level provided by the public ledger with respect to the number of monitors

Supply chain management includes the planning activities and it get affected negatively which by the influence of algorithms if there are asymmetries in the information among the actors. Due to the complexity of the supply chains, it has become a complex task to coordinate the information. Nakasumi et al (2017), addresses this issue and makes the important aspect of data sharing among the customers, manufacturers and suppliers efficiently as a vital point. There is a risk of data tampering when its control is centralized and within the authority of service provider. Conventional traceability system stores the information in centralized database and this issue was identified in the paper of Lu et al (2017). They developed a concept called *Origin chain* which uses the application of blockchain to automate regulatory-compliance checking to eliminate centralization of the system and to make traceability tamper-proof.

Similarly, Wu et al (2017), addressed the inability of the existing system to track the shipment and these existing systems are limited and are not validated by an independent entity. To counter this issue, the paper proposes a framework, which consists of single blockchain public ledger and a set of a private distributed ledger for tracking of the shipment online. The stakeholder receives all the information regarding the distribution phase that will increase the visibility of the whole supply chain process. The researchers attempted to address the

classification between the architecture of private which require permission and public blockchain which are completely open. Another instance identified by Merkas et al, 2018 is where the application of blockchain utilized when the information regarding the cargo is not aligned with the route, thus leading to difficulties in planning the operation. The technology allows every actor involved in the chain of logistics to register essential details including all the operations and planning. For instance, the truck capacity can be shared in real-time with the third party and this can significantly decrease the cost of integration between the shared information and the operating system. Using smart contracts or Ethereum among various actors can result in a more efficient process with reduced need for intervention and paper works (Merkas, 2018).

2.2.8 Blockchain application to integrate Logistics and Smart transportation

1.Payments and traffic conditions

Bagloee et al. (2019), introduces to the concept of *Tradeable mobility permit* (TMP) to contend traffic congestion and to support their proposal a numerical test has been performed and tested. The paper formulated smart contract to address the congestion occurring due to traffic with numerical analysis. Various application of TMP and smart contract are also discussed, such as the benefactor for the dynamic toll pricing, platooning of heavy trucks, emergency and connected vehicles. These permits are tradeable in an open market like bitcoin (Bagloee , 2019). The logistics company could use these permits as a credit system for a variety of payments during transportation which includes Vehicle registration fee, toll payments etc. The paper also proposes ways to benefit this technology by implementing it on the platooning platforms. To reap the credit and to encourage the platooning of trucks, it is likely to consider a positive credit incorporated with the leading truck to the extent that the following trucks will join the platoon. To attain a realtime data related to speed, acceleration, position, trajectory, brake etc, an *On-Board Unit* (OBU) on the leading truck and *Road Side Unit* (RSU) can be installed at roadsides or at various traffic signals. However, there could be many other factors such as road accidents, maintenance etc which could lead to delay during the transportation of goods other than just the congestion due to traffic. Those factors are not considered but the concept seems to have a huge scope on a real-time application if all other factors are considered.

2. Concept design and incentivization

Tasca et al. (2017) can be referred as a guide for exploring a blockchain-based concept design for building the architecture for incentivization. They recognise and classify the main components of a blockchain and their relationships which will help in designing the concept. The main components to be considered are *Rewarding system* (incentivization), *Vehicle charging, identity management, Extensibility* (interoperability with various systems), *Privacy* and *security, Tokenization* of native currency, *Consensus mechanism* (ensuring

trustworthiness) and *Transaction capabilities* (scalability) (Tesca, 2017). This approach could be used to provide incentives to the logistics companies operating in a platoon to increase the willingness to lead other trucks as the following truck have the benefit of gaining more profit from saving fuel and manpower compared to the first truck. However, the major drawback that could occur while executing incentivization is when these concepts lead to issues of practicality for their users and when the intuition and the experience of the researchers are considered while such a system is designed. Furthermore, the researcher does not hold a juridical background or experience that could provide a detailed insight into the General Data protecting regulations. Moreover, the focus is more on its futuristic scenarios which involves a high level of uncertainties when it comes to its feasibility.

2.2.9 Challenges associated with the technology

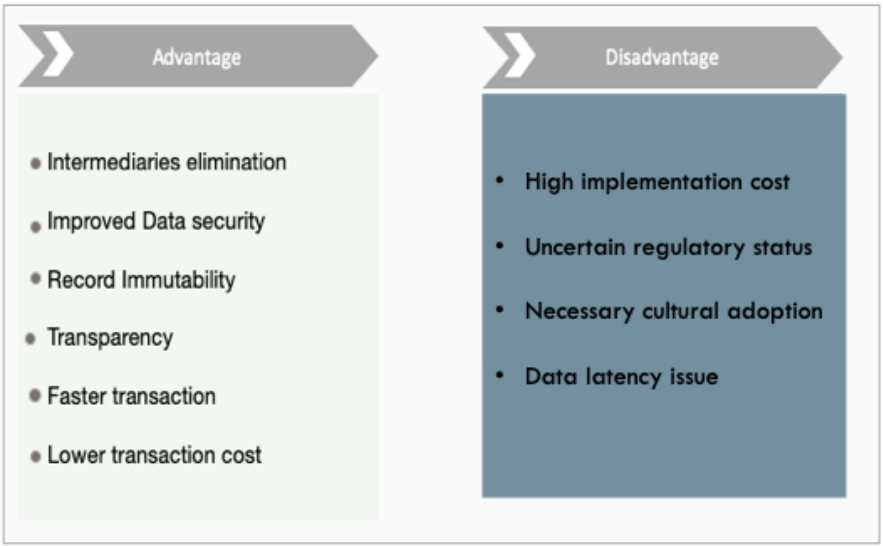


Fig 4.4. Advantages and disadvantages of implementing blockchain

Fridgen et al. (2019), present an interdisciplinary study on the challenges and the opportunities facing the use of blockchain as a decentralized system in Logistics and mobility in a perspective of technology, economics and law along with specific case studies which could be blockchain-based (Fig 4.4). The study states that the decentralized ledger system has developed into a widely usable basic digital solution for economic infrastructure that is currently approaching market maturity and present case studies on shipping documents, ridesharing, and intelligent transportation (Fridgen, 2019). According to his research, the platooning could benefit more than the conventional system and can be considered superior if the decentralized ledger technology is implemented. It is also unpropitious that the blockchain will lead to new monopolies (Fridgen ,2019). Nevertheless, it is important to have a combined effort of the state and the free democrats to shape the solution and the systems.

There are a number of challenges associated with the implementation of blockchain technology in the intelligent transportation system. There has been a lot of researching going on in this field lately, but very few studies implement a real blockchain. Astarita et al.(2020), addresses

the technology as immature as it is not yet ready for large scale diffusion. The technology consumes a large amount of energy and requires a great number of computational resources (Newman, 2018). Computer redundancy is not energy efficient but the safest consensus mechanism used in blockchain technology is dependent on that. Moreover, the latency issue when it comes to connected vehicles, there could arise a problem when all vehicles are using smart contracts and a rise in congestion in the wireless network. Identifying this, Singh et al. (2019), share concerns regarding latency issues in real blockchain applications. In order to overcome the issue of latency, Kim et al. (2018) propose to reduce the mining time of a block and divide the blockchain into multiple chains. Before technology becomes universally adopted, there are certain hurdles that need to be taken care of and that includes trust issues, cooperation among stakeholders and the responsibility of taking up the development and set up cost.

2.3 Overview of the research papers

Table 2.1. Overview of the research papers and its level of implementation

Authors	Level of implementation	Issues identified	Contribution
Wu et al (2017) Logistics management	Concept with proof	Inability of the existing system to track the shipment -these existing systems are limited and are not validated by an independent entity	Framework that leverages communication among the actors, distributed database and the BC technology to deliver information regarding the tracking of the shipment.
Nakasumi et al (2017) Logistics management	Concept with proof	Asymmetries in the information among the actors	Addressing important aspect of data sharing among the customers, manufacturers and suppliers efficiently
Lu et al (2017 Supply Chain management	Implementation based on real blockchains	Centralization of the system and to make traceability tamper-proof	Developed a concept called *Origin chain* which uses the application of blockchain to automate regulatory-compliance checking
Dorri et al. (2017) Interconnected Vehicles	Concept level	Sensitivity of data exchanged between interconnected vehicles such as platoons	Decentralized blockchain-based architecture for a smart vehicle ecosystem to enhance the security and protect the privacy of the user
Yuvan et al. (2016) Interconnected Vehicles	Concept level	Trust issues among the actors leading to the complex information flow	Case study for real time ride sharing services based on blockchain which is aimed at stimulating guidance for future research work in this new direction
Lei et al. (2017) Vehicular networks	Concept level	Complexity in distribution and simplify management	Illustrates a system to reduce the transfer time of blockchain schemes by flexible transaction collection period selection method
Yang et al. (2019) Vehicular networks	Concept with proof	Trust values within the vehicular networks	Decentralised trust management system by employing a joint *Proof of work* (Pow) and *Proof of stake mechanism* (PoS) to evaluate the performance

Bagloee et al. (2019), Traffic and external factors	Concept with proof	Traffic congestion, dynamic toll pricing, platooning of heavy trucks	Use *Tradeable mobility permits* as a credit system for a variety of payments during transportation
Tasca et al. (2017) Incentivization and reward system	-	Complexity in reward system and incentivization	Guide for exploring a blockchain-based concept design for building the architecture for incentivization
Lu et al. (2018) VANET	Concept level	Rising ITS complexity which includes large data storage, information security and intelligent management	Propose a trust management system for VANET with the application of blockchain which works on a reputation score mechanism based on historical interactions
Xiaodong et al. (2018) VANET	Concept level	High amount of data generated by VANET	Implementing *Mobile edge computing* to balance the resource consumption in VANET
Javaid et al. (2019) VANET	Concept level	Privacy and the communication security issue	Concept based on *Physical Unclonable Function* (PUF) and blockchain called *DrivMan* for data sharing and trust Management in VANET with the help of Ethereum and two smart contracts

2.4. Conclusion

The application of blockchain provides a way to face the difficulties of improving and protecting intelligent transportation leading to a sustainable industry 4.0 consequently enhancing security in the entire supply chain. This research has been receiving increased academic attention and in coming years the number of literatures is about to double. This distributed ledger technology generates transparency leading decentralized ownership that tracks the movement of the goods from origin to the end customer monitoring throughout the supply chain. The authenticity of documentation can be validated using smart contracts by eliminating complex paper works. Information regarding any transaction is circulated among all the actors since each one of them holds a copy of the ledger enabling the execution of conditioned and long-term contracts. Acknowledging the research conducted for this study, it can be inferred that information asymmetries and perplexing supply chain can be prevented utilizing the application of blockchain. The open access to the ledger and the authority to register the handling throughout the supply chain can overcome the challenges mentioned. The information regarding the products, supplier and the mode of transportation is made transparent which can be accessed without any hassle. This could level the imbalance between the strong and the weak networks.

In terms of transportation, smart contracts could solve the complexities involved by validating and executing the conditions in a contract automatically. A decentralized heterogeneous transportation system can be created by eliminating the issue of trust and enhancing security with the application of this technology. Moreover, complex operations could be simplified, for instance, incentivizing the leading truck in a platoon since the following trucks gain more profit in terms of labor and fuel consumption. Vehicular Ad hoc networks can be enhanced by implementing blockchain in intelligent vehicles and can be used for platooning and driverless trucks for the purpose of goods movement. Furthermore, electric charging of these autonomous trucks could also be made possible with tradeable mobility permit and smart contracts by promoting a secure mechanism for auction to match the supply of energy and demand for vehicle charging.

The purpose of this literature review was to contribute to the potential implication of blockchain technology within the research field of the logistic sector operating on intelligent transportation. With the utilization of blockchain, all the concepts mentioned in this review can be made possible. Nevertheless, more studies have to be conducted to understand the better scope and practicalities of this technology particularly in the integration of logistics and intelligent transportation.

2.5. Knowledge gap

This literature review is an effort to understand the potential implication of blockchain technology within the research field of Logistics and automated transportation. There is a huge potential for this technology in terms of traceability of goods and ensuring sustainable transportation process. However, more research in the field of blockchain integration with automated transportation for logistics has to be conducted to understand the barriers that could occur during actual practice. According to this study, blockchain can be considered as a substantial factor in reaching the objectives of implementing automated transportation in logistics.

This literature review used the most notable cases of blockchain technology in logistics synthesis with smart transportation, but there should be future research deepening more into a quantitative approach. Most of the projects are in the early stage and it is difficult to attain high-quality data. Moreover, they are conducted often in lab-based facilities which lack real-time scenarios. The current researches are mostly focused on the positive impact of this technology and therefore future research should investigate the negative impact of implementing this technology in the field of Logistics and transportation.

There is very little knowledge about the technology's actual application in process improvement and the logistic sector. Blockchain technology has been termed as a disruptive technology by many industrial expert and consultancies in different disciplines. However, research on identifying the contribution of the technology specifically in developing automated transportation for hub-to-hub logistics is scarce. Furthermore, concerning logistics, often only possible future use cases are described, with no further evaluation of feasibility or critical

aspect on potential challenges. Hence, this thesis contributes to expanding the current literature on blockchain technology in application to introducing automated trucking in hub-to-hub logistics and determining the impact of the technology for real-time use cases in the domain.

3.Container Terminal Operation

In this chapter, the process and the information flow at the hub (CTT terminal) is studied to identify the areas where blockchain technology can be applied. For the same, desk research is carried out along with interviews with the officials at the terminal. Furthermore, visiting the Port terminal has helped to understand and capture the real-time operation flow and identify the bottlenecks associated with the process. As a part of introducing automation to the terminal, different levels of digitalization are studied, followed by identifying significant technologies that enable the implementation of blockchain applications more functionally and efficiently. Additional values that blockchain technology can provide by its implementation to the system are also determined based on operational aspects at the terminal.

Fig 3.1 Operation types in container terminal Henessey 2019

The unloading process is crucial in the terminals that manage incoming containers from the vessel. This process can signify the process automation of container handling at the port logistics due to the high use of Terminal equipment and stack of containers. Considering container terminal as a system, Henessey et al, 2019 categorised operational areas as Vessel, Berth, Intralogistics, Yard, and Gate (Fig 3.1).

Terminal operators encounter difficulties in overcoming the unproductive and expensive container movements if the vessels are not handled efficiently. The estimation of cranes to be used is based on the size and the volume of the containerships. The shipper will send a copy of Bill of Lading (BoL) to the consignee before the vessel arrives. This is a legal document that act as proof of a contract of the containers, receipt of goods and document title to the goods and will allow the consignee to arrange the customs clearance and final delivery. The one who owns the BoL has the legal right to claim the goods. This also allows them to transfer the ownership to another party when the BoL documents are handed over. The party retains this ownership until they surrender the BoL. However, the shipper will surrender the BoL when there is no due on balance payment.

Generally, the planning of the vessel is carried out within twenty four hours prior to the shipping line calls a vessel (Henessey 2019). For manifesting the planning process , a list of

containers to be loaded or discharged is incorporated in the operations . Once the containership is arrived, berth location is assigned and vessel is docked at the specific location assigned. The size of the container, equipment specifications (cranes/ straddle cranes/ terminal tractors etc.), service facilities and handling capacity are the major characteristics to be considered while providing berth location (Imai, 2005).

Containers that are to be stacked are transported to the yard from the berth and placed in area for dispatch . These processes comes under the Intralogistics operation where a central database at the terminal will store all the major import information related to the container such as its weight, vessel number and all other relevant information. Based on the availability and operational requirement, yard tractors/ straddle carriers are assigned to support the transportation within the terminal in this operation. The central system (database) at the terminal will be updated /notified when the containers are transferred from a location in the yard. This will allow the terminal operators to identify free area and load/ unload containers on a vessel using Quay cranes (QC).

Furthermore, these containers' storage period are divided into three types: long-term, short-term, and specialized. The location for the container until it is loaded or dispatched in the container storage system is assigned manually. A specialized storage will be used for containers that are empty or that contain hazardous/ refrigerated materials,. Finally, the interface to different modes of transport that connect the hubs lies in the gate system. Information regarding containers is attained by managing the gate (Henessey, 2019) The containers coming into the terminal are physically handled properly before trucks are arrived. It is an important area where the access need to be controlled and the secured functioning of the container terminal depends on the effectiveness of managing the gate system.

3.1 Primary Functions of Terminal operation

The scope of this research will include identifying areas where blockchain technology could be introduced into the system so that the process could be more transparent and secured. The problem area will be limited to the process starting from receiving the BoL, unloading the container from the vessel to the respective storage location, i.e., the berth, yard, or the debtor's warehouse. The study will also focus on the transportation of the containers within the hub, including Intra-logistics vehicles such as cranes, terminal tractors, trucks, etc. Furthermore, the gate system will also be considered to identify more efficient ways of improving check-out and check-in of containers at the terminal. Different processes are required in the execution of the operations mentioned above and primarily functions such as exchange of information, tracking, sorting, asset management and scheduling are to be considered for efficient handling of containers (Hennesy, 2019):

It is vital to exchange information such as the shipment status to validate and verify the freight transport. For the same, responsibilities are defined, and the exchange of documents among various customers is considered to be necessary. Various tools for sharing, processing,

visualization, and analysis are being used to execute major operations, including allocating storage areas, scheduling, and other major management tasks. Furthermore, Identifying and locating the assets are correspondingly essential in terminal operation. Higher productivity results from enhanced visibility of assets, for instance, the equipment to handle the containers such as cranes, tractors, trucks etc. Sharing such information can lead to higher productivity and therefore can be considered as a vital function.

The incoming containers are constantly sorted based on the requirement and defined criteria in the terminals to control the operations efficiently. For the same, proficient knowledge and the use of the intelligent system are required to execute the decisions. Several functional equipment types are being utilized at terminals to handle containers. One of the significant objectives of terminal operators is to efficiently use human resources, equipment, space, and other resources to attain a high-performance rate at minimum operational cost. However, several uncontrollable variables affect the ongoing process in the container terminal, such as the weather, congestion, strikes, etc. Therefore, It is important for the containers arriving at the terminal to coordinate with the schedule of the operations at the yard and to check the availability of manpower for transferring the containers.

3.2 Digitalization of process

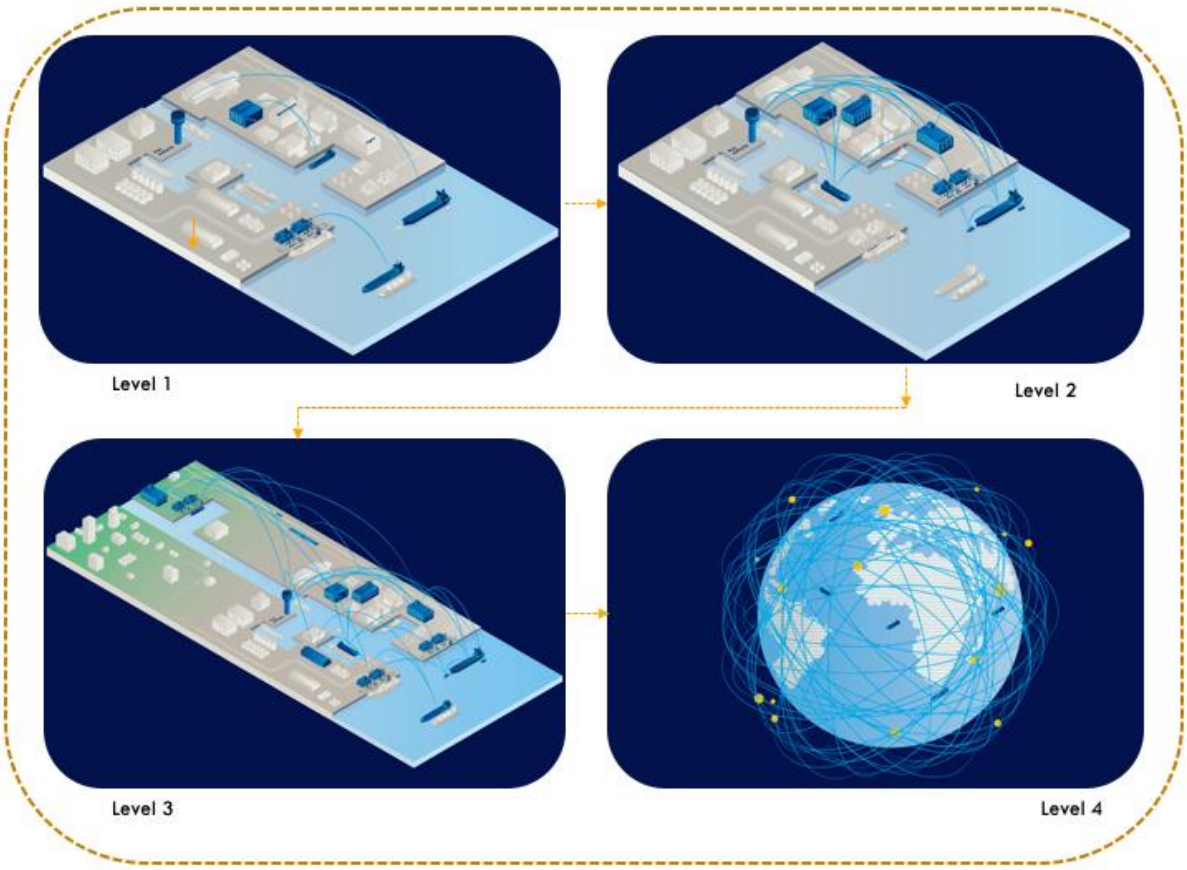


Figure 3.2: Digitalization levels (Buck, 2020)

Digitization refers to converting analogue data into digital format, that is, binary numbers so that the computer can understand it. Digitization means that an organization or industry adopts digital or computer technology. Therefore, digitization involves a transition from conventional manual paper work to a more efficient computerized version. Digitization has a unified group of digital activities in an association or industry to simplify and improve the organization's efficiency and performance (Buck, 2020). There have always been discrete digital processes or operations since the beginning. As the digital transformation progresses and combines with other functions or operations, we can better understand the organization and promote better coordination of planning and execution of the activities. Therefore, each step towards digitization can be considered as a bigger step towards Digitalization. This will help to implement new business models and create new value propositions (Buck, 2020). This is achieved when the organization integrates digital workflows and processes. For the same itis essential to analyze digital strategies and identify an integrated system that helps to better coordinate and analyze operations. and is open to adopting future technologies. The core of digital transformation or digitization, which is a continuous journey, is aimed at simplifying and improving organizational efficiency and performance. However all this is possible if all the stakeholders/ actors are open to adopting future technologies.

According to Buck et al, 2020, digitalization is classified into 4 levels (Figure 3.2)

Level 1: Single process or operation in the port is digitized. In this level, different stakeholders such as Port Authority, terminal and nautical service providers can function efficiently. It starts from an inter level operation extending to intra level operations throughout its phase of development.

Level 2: Combining Operations with other processes and work concurrently to improve efficiency. The digitization of individual processes further heralds exchange of information digitally within the port community. This will result in a more reliable, paperless and efficient data flows.

Level 3: Synthesis with inland operations is made possible in this level: Hinterland operators' communication within the Port community are also involved in this level of digitalization. Information from the Port community system is shared with the terminals, carriers, empty depot etc. Moreover, the parties at the hinterland can receive real-time insight regarding the cargo and based on which efficient planning can be made possible.

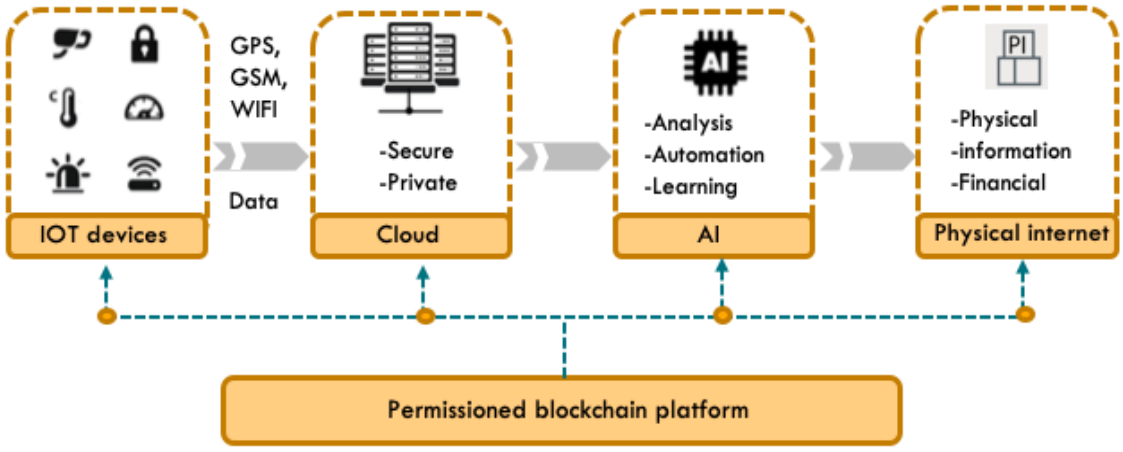
Level 4 : Collaborating several hubs and coordinating the activities globally to effectuate the concept of connected hubs are made a reality in this level of digitalization. The communications between a terminal and its hinterland are extended to other ports globally. This, in turn, is digitally connected to their own hinterland. This leads to a combined one-to-one digital logistics chain globally, making excellent use of various modes of transport.

Digitalization can be viewed as an ongoing process across the ports and industries based on the levels mentioned above. The course of digital transformation starts from a lower level of

digitization to a higher level. For introducing digital transformation within the terminal, it is necessary to consider these levels to realize the intensity of changes that could be bought into the system when a technology like a blockchain is implemented.

3.3 Enablers of Terminal digitalization with blockchain technology

The blockchain-based system at terminals can facilitate heterogeneous organizations to exchange data for collaborative decision-making securely. For example, unlike just the physical transfer of business documents, the technology can digitize the whole document processing procedures to aid authorized users in accessing information stored in the ledger by respective stakeholders (Yang, 2019). Thus, stakeholders involved in terminal operations can attain relevant and valuable data in real-time with minimum transaction costs. Blockchain technology's secured, and transparent characteristic has had a notable impact on the adaptability of the technology to port logistics operations. However, for introducing this decentralised technology, it is important to look into other technologies that can be an aid to the functions of blockchain technology and implementing the automation hand in hand. The following technologies depicted in figure 3.3 has the potential to enable the blockchain technology in enhancing its operability in the logistics industry.



.

Fig 3.3: Enablers of blockchain technology (own composition)

3.3.1. Internet of Things

The container shipping management can be significantly affected by the actions and the decisions taken by the stakeholders. However, the Internet of things being an emerging technology can impact the stakeholders to effectively perceive, share and observe limited resources to improve efficiency and productivity. New business models can be achieved by introducing digital technology, which can give a competitive edge to deliver higher productivity and continuous improvement in the system (Lee, 2018). In addition, they can assist in the automation of port terminal processes, such as tracking and tracing goods, sorting of

goods, protection and automation of port documents, management of port terminal resources and assets.

Sensors installed in port terminals to collect the terminal's data can be considered an example by which an optimal design for stowage plan can be generated to load or unload the containers on ships. In addition to this, yard management can be made more efficient by proposing an IoT based system for stacking containers based on containers storage duration. Furthermore, automated and unmanned conveyors to automatically move containers around the terminal can be used for intralogistics services to minimize total transportation cost (Bavassano, 2020). However, all the data determined can be stored using blockchain technology and shared among stakeholders securely.

With the advancement of barcodes, OCR (Optical Character Recognition) and RFID, the trucks and the containers are registered at the gate (Bavassano, 2020). These are connected to a system that can store data and can be used to track the containers at the terminal and can store all the relevant information related to the shipment that can also help in clearing custom formalities if required. The terminal operators can effectively plan the movement of the containers and the storage with the application of IoT (Chen, 2013). This information can be stored securely and can be accessed with the knowledge of all other stakeholders using blockchain technology, making the whole process more transparent.

3.3.2 Physical Internet

Benoit Montreuil in 2011, developed the vision for the future of how physical objects can be transported, handled, stored, supplied, realized, and used across the world by introducing the concept of Physical Internet. Coordinating several potentially conflicting objectives requires a flexible supply chain design, combining the physical chain with the chain of information and financial support (Meyer, 2019). In recent years, emerging technologies such as the Physical Internet and blockchain have attracted extensive attention from academia and professionals due to their prominent role in technological innovation. In a blockchain, the transactions are interpreted sequentially in a decentralized manner and stored in the distributed ledger, thus making the data permanent and tamper-proof. However, the Physical Internet aims to create a logistics system that is accessible globally by interconnecting the existing logistics networks (Montreuil, 2011). Moreover, to achieve this, a set of protocols are standardized and intelligent interfaces are implemented. The Physical Internet is a complete and measurable supply chain framework based on a network of physical components (Meyer, 2019). These components undergo standardization and optimization to share information, enhance the efficiency of the operations.

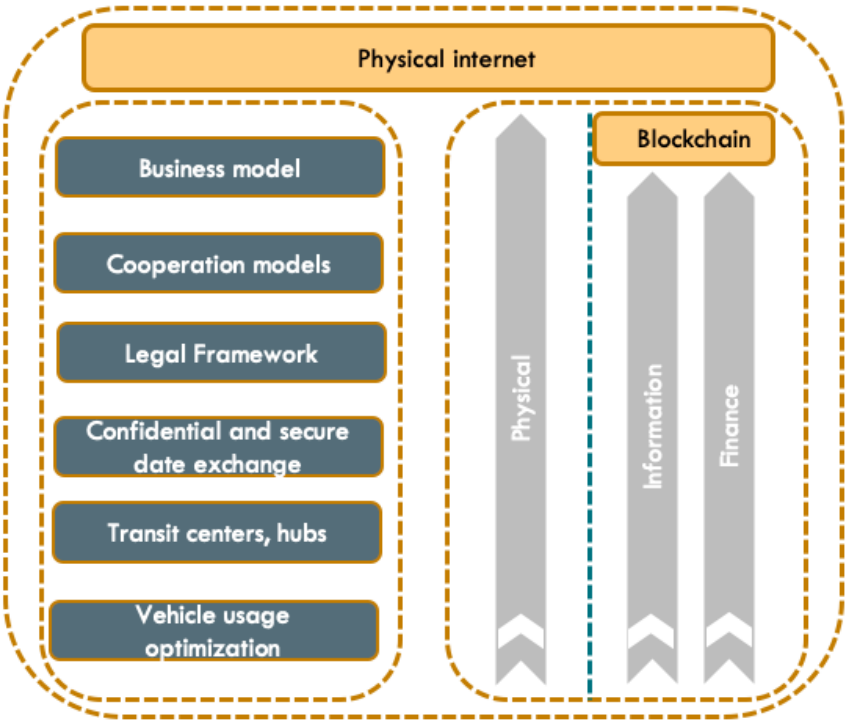


Fig 3.4 Physical Internet (PI) integration with blockchain (Treiblmaier, 2019)

Treiblmaier et al., 2019, introduce a framework that combines the PI with blockchain technology. The layer at the bottom deals with the use and optimization of vehicles, including the sharing of means of transport, which can ensure high productivity and energy efficiency. The layers mentioned in the framework (Fig3.4) provide fully functional designs for handling modern and open transit centres to execute efficient freight processing. The transparent and safe data exchange that are sensitive can be attained through shared and secure protocols. According to the framework, PI includes significant aspects such as legal security, the equitable sharing of revenue (cooperation model), new business model generation etc. (Treiblmaier, 2019).

The physical information and financial flows are shown on the right-hand side of the framework, in which the flow of goods represents the physical supply chain while finance and information flow plays a key supporting role. The PI plays a major role in each individual layer and also in connecting one layer to another. Nevertheless, blockchain technology covers non-physical layers, i.e. the flow of information and financial flow in payments. Different perspectives on logistic operation are integrated with this framework. The researcher points out the ability of the technology to bring improvements in each layer even without considering adjacent layers (Treiblmaier, 2019). However, the features and functionalities of the technologies can support the implementation requirements of each technology and overcome critical barriers.

3.3.3 Artificial Intelligence

The introduction of digital technology in terminals has been slow, but it is under steady development. Researchers have used different methods to address several problems faced by planners and managers of ports and container terminals. Studies have been carried out to propose tools for supporting decision making related to the yard and crane management. Simulation techniques/ tools can be considered state-of-the-art technology to test strategies related to decision making and compare with real-time experience.

Researchers are working on Multi-agent systems to solve distribution problems, such as transporting containers from docks to yards or distributing transport equipment for moving containers within the docks by employing simulation. For instance, Hartvanyi et al., 2005, designed a proposal emphasising cooperative behaviour to handle the movement of containers and place them in storage blocks in the yard. The conceptual model was designed to distribute information between terminal managers, customers and operators, thus improving the cooperation among the actors involved in the process. Lokuge et. al 2007 depicts that if agents have certain behavioural aspects, the artificial intelligence technology can learn those aspects and modify the system, thus intensifying the scope of automation.

The information management system allows the terminal administrator to monitor and control the process. As the studies propose, simulation techniques are an excellent way to process raw data and obtain information about the operation under observation. Rida et al., 2006, used a visual interface in the simulator to test and run hypothetical scenarios to evaluate management strategies. Furthermore, Chowdhury et al., 2007, proposed a model to exchange information in real-time, which will simplify the flow of information among various stakeholders. Consequently, these tools can help to make operational decisions by predicting traffic conditions resulting from incidents. Another simulation-based decision tool related to terminal operation is given in the research done by Guo et al., 2012 for the loading of containers employing yard cranes. This research uses the information tracking system to predict vehicle arrivals to simulate hypothetical simulations in real-time and schedule yard cranes.

3.3.4 Cloud computing

To store a substantial amount of data, the container terminal or the Port authority can use cloud computing technology that runs under a high-performance computing system, resulting in minimum ownership cost of the assets. Tsertou et al., 2016 indicated a cloud-based information system/ portal for various actors involved in the process to link IoT sensors for real-time information analysis. This can reduce the complexity of processing multiple information interfaces, especially for small and medium-sized ports and other entities.

Heilig et al., 2017 conceded the purpose of having an integrated cloud based platform for real-time routing of trucks within the container terminals. Data mining technology improves route prediction to evaluate potential bottlenecks in container routes. Availability of transparent and real-time information is the fundamental value of the process and operation of dynamic

terminals. The fusion of operational data from information systems and sensory input from IoT's and the use of cloud and communication technologies brings various opportunities. However, as a centralized governance technology, cloud computing has some potential shortcomings regarding privacy, data security and network maintenance costs. The use of decentralized and distributed technologies such as blockchain can ensure a reliable, auditable, safe and transparent operating environment for all associated stakeholders involved in the process.

3.4 Value Creation using Blockchain technology.

A resource is valuable if its capability can permit the organization to decrease operational costs and prevent any damage or threat to the environment. This should be considered a top priority for any company to deploy resources or capabilities to gain a competitive advantage effectively. After understanding the process and procedures of terminal operation, this research will focus on blockchain technology's value creation concerning various operational aspects. Blockchains decentralization capabilities, compared with centralized servers/databases, some of the key advantages are identified, and they are as follows:

Immutability: The decentralization and implementation of storing data on the blockchain make it impossible for any party to alter the data or records without the consensus. However, compared with the prevailing situation, if the data is stored on a local computer/ network, it can be altered or modified, which reveals the lack of trust and security in the system.

Security: Servers or data are normally centralized and are exposed to malicious attacks. However, the decentralization of the data using blockchain dramatically increases the complexity of such attacks. As the number of participants/ nodes increases, the more each node has to verify the copies of data. As a result, if someone initiates any malicious attack or changes something (without consensus), they will have to attack each node available in the network and make changes to all the data simultaneously. This is not practically possible since each block contains a specific amount of data, and these blocks are sealed and encrypted when the block become complete. To crack this security system is almost impossible technically and can be an expensive task.

Redundancy: There is no risk of losing data by using blockchain technology since all the same data set is shared to all the stakeholders regardless of distance. This ensures data resilience, giving confidence to the organization by eliminating all possible ways of losing data.

Cost reduction: The decentralized network created using blockchain technology will allow organizations to mitigate the distress of keeping a ledger for custody, requiring high security and maintenance costs. Furthermore, this can eliminate the cost of maintaining IT staffs and infrastructure costs. Companies, for instance, have to keep monitoring the system to protect themselves from malicious attacks throughout the year. However, the introduction of blockchain technology can save this huge cost for monitoring.

Accountability: Keeping records on the blockchain can be considered accurate and valid. For instance, the information related to the exact location of a container location, yard allocation status etc., can be stored and shared among relevant actors. This increases trust and enables companies to conduct business transparently. Unfortunately, the current data infrastructure can only partially accomplish this. Still, the only basis they have not been withdrawn is that no technology could provide significant improvements before the advent of blockchain.

All these characteristics of blockchain technology allow the organization to improve the effectiveness of specific processes, strengthen trust, and create new business models. Furthermore, enhancing internal processes implies reducing operating costs, thereby decreasing costs for customers. This can result in increased customer satisfaction and conceivably allow them to ship more commodities. So implementing higher transparency and thereby gaining the trust of customers will lead to sustainable market size because customers will have more confidence doing business with operators that adopt transparent technologies. Moreover, the emerging technology may attract more customers, and they will apprehend that the industry continues to provide more and better services. Together, these elements create continued competitive advantages for operators and can add lasting value. This study will incorporate the values identified and the primary functions of the terminal for executing a blockchain-based system.

The incompetence of the traditional system greatly affects the efficiency of terminal operations since they lack the sharing of synchronized, reliable and consistent information with all stakeholders. The chapter infer that adopting intelligent technologies can prompt terminal and port authorities to use cloud computing technology, the Internet of Things (IoT), Artificial intelligence and Physical internet to achieve port and terminal automation. Some of the goals of terminal operation automation include maximizing profit, minimizing container handling costs, improving resource utilization efficiency, and minimizing terminal congestion (Anwar et al., 2019). However, all these goals can be achieved by digitalizing the process and blockchain technology can accomplish the digitization of port terminal operations to subdue these barriers and provide tamper-proof data (Anwar, 2019).

4. BPMN and Scope for digitalization

The objective of this chapter is to interpret Business Process Model Notation (BPMN) for determining the current and improved flow of the process at the terminal. The areas where digitalization can be introduced is identified. The primary goal of BPMN is to provide a graphical notation that is understandable by all business users. The users include the business analyst who creates the initial draft of the process to the technical developer responsible for implementing the technology that will perform those processes, and the business people who will manage and monitor these processes. BPMN follows the tradition of flowcharting notation for better readability and flexibility. In addition, the BPMN semantic is completely formalized. A "Process" is a sequence or a flow of activity to execute work. In BPMN, the process is depicted as a graph of flow element, a set of activities, events, and gateways connected using sequence flow. The sequence flow is used to show the flow elements in a process.

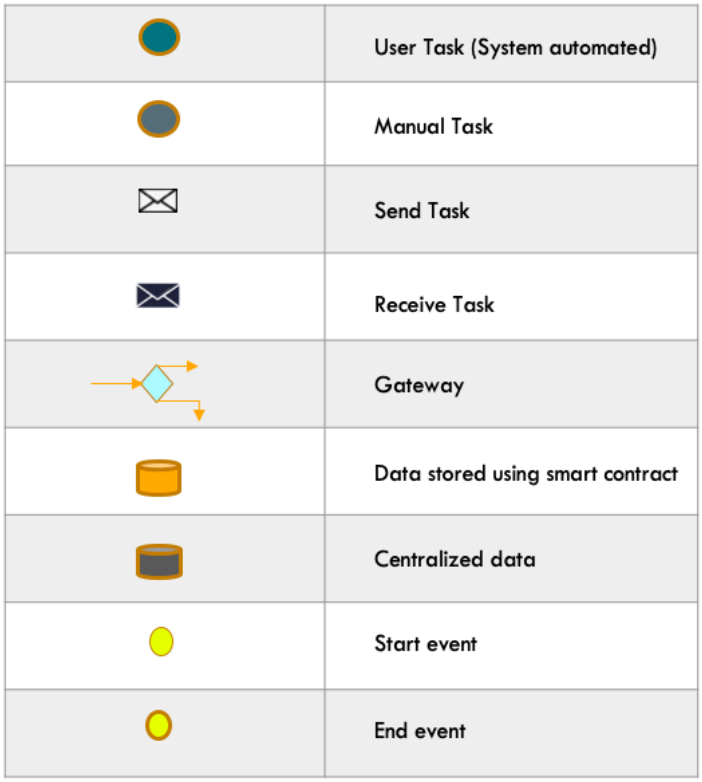


Fig 4.1 Tasks carried out in BPMN (own composition)

Different tasks are carried out in the process flow, and those which are applied in this case are represented in fig. 4.1 . "Send task" is designed to send messages and "Receive tasks" waiting for the message to arrive. Once the message is received, the task is completed. "User task" is typically a workflow task where a human performs a task with a system or software, whereas a "Manual task" is expected to be carried out without any software application aid. Furthermore, an "Event " in BPMN happens during the course of the process and affects the flow of the process. The "Start" event starts the process and cannot have any incoming flow;

however, the "End" event indicates when the process will end and hence will not have any outgoing sequence.

To control the flow of the process, " Gateways" are used, which apply a gating mechanism that either allow or deny access through the gateway. It can have multiple inputs and multiple output flows. Finally, the traditional requirement of the process is to be able to model items (physical or informational) that are created, manipulated and used during the execution of the process. These physical or information items include data input and data stored; however, these items do not affect the process modelling flow. This study provides the representation of both current and improved processes through the BPMN diagram.

The current process is determined after understanding the terminal's real-time process flow during the unloading process through interviews with the terminal operators and by visiting the XL business park in person. The process is studied in depth to identify the areas where improvements could be b76025345ought using blockchain application and based on which the new BPMN is generated.

4.1.1 Communication & Planning at CTT

The communication and the planning process is studied in this section to determine the areas where digitalization can be implemented. All the information is attained through interviews with the terminal operators and on-site visits to the XL Business park to better understand the real time process. The figure 4.2 depicts major stakeholders involved in the process . The communication and the planning is executed among these actors to carry out the process at the terminal .

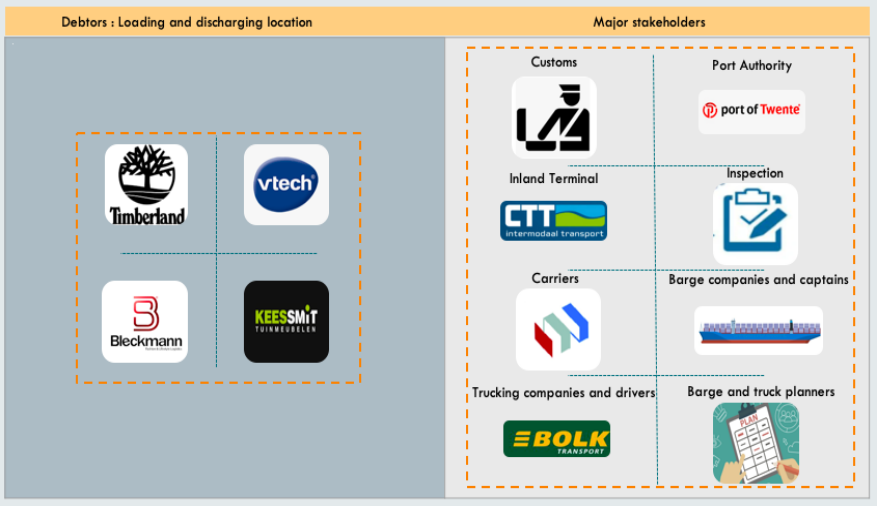


Figure 4.2 : Major actors involved in the process (own composition)

- Communication is mainly by the customer service desk by phone (with clients), mail, by EDI (Electronic data interchange): old standards for exchanging files with information with text files, by API (Application programming interface)
- Communication with the barge: phone or the barge-app

- Communication with the truck: Computerised system in the truck (truck app- Informs the driver where he needs to gate out/ in) . Human Planner inputs information in the Modality Transport Management System, and then the truck app transfers it to the truck driver.
- Camera system (Hengelo): Truck and container details are captured. This creates several timestamps registered in the CTT communication system.

Timestamps : Arrival time
Start handling time
End handling time
Leaving time

During the interview , the Container Terminal Manager gave the following comments on the bottleneck concerning the current process:

- Time update depends on the communication of the timestamps between the terminals. It is currently being done manually; therefore, there is a scope to improve it or automate it.

- Interpreting 6 to 7 thousands of transports are being considered a challenging task at any given moment by humans.

- Change in planning is crucial, and it cannot be done on short notice because the information has to be communicated with many parties.

CTT currently has a centralized planning system (Human planners) for all the 3 locations (Hengelo, Almelo, and Rotterdam). They plan all the barges and trucks and make sure there is coherent planning.

4.1.2 Current Business Process flow at the Terminal

In this section the research will utilise the unloading process of the container terminal as part of a case study to demonstrate the implementation of blockchain technology. The unloading process is one of the important processes for the logistics terminals to handle the incoming containers from the ships. Due to the high usage rate of machines and the large number of container queues, this process may represent the automation of the container handling process in terminal logistics. The process is divided into 5 operational categories, which are; Yard container, Terminal, Transportation, Debtor and Customs. To simplify the system, this article opts to focus on the process from unloading the container to placing the container in its respective location . Figure 4.3 represent the process flow in a BPMN format.

Once the ship arrives at the port, the unloading process can be started after the management tasks related to the incoming container are completed. Furthermore, the designated quay crane unloads the container from the ship to the quay tractor. These vehicles receive containers and transport them to designated storage yards. When the tractor reaches the destination point in

the yard, the yard crane starts unloading the container from the tractor and stores it in a specific block in the yard.

A barge arrives once a day at most at CTT Almelo from Rotterdam or Hengelo and departs to Rotterdam or Hengelo. After arrival, the barges are unloaded by a quay crane. Directly under this crane are the stacks and at the end of the range of the crane is the truck lane. Trucks that are delivering or picking up containers are also used for transport outside the XL Park. This truck transport is managed by Bolk, the truck transportation company of CTT. Trucks are also used to transport containers between CTT Rotterdam, CTT Hengelo, and CTT Almelo, when it is more convenient than barge transport, for instance, when a container has a tight delivery date, but there is no barge scheduled to be able to make that date. Another case is when it is not beneficial to stop in Almelo for just a few containers and then continue to Hengelo, since it takes at least five hours to make this detour, it is more profitable to send the barge directly to Hengelo and transport the containers by truck to Almelo. However, there is never any truck transport on the XL Park. The yard tractor is dedicated to transport the containers to and from the companies on the XL Park. Furthermore, the transport of containers by the yard tractor is managed with chassis.

A container can be placed on the chassis by the crane without further human interaction. The operator of the yard tractor can pick up the chassis by manually coupling the chassis to the yard tractor. The operator must check if the container number is matching with the right container to transport. The operator has to put the delivery documents on the back of the container for the client once the discharge is done. Arriving at the client, the operator of the yard tractor must get through the gate. At Timberland (debtor) this works with a camera, or the operator has to call the front desk to open the gate. Furthermore, the operator can choose a dock to park the container and decouple the chassis once the container is at the destination. Also, at some instances, the operator receives a dock schedule for parking the containers. Finally while returning the operator check if there is an empty container to take back to the terminal and If there is an empty container ready, couple the chassis to the yard tractor and drive back to the terminal and park the chassis with an empty container on an empty spot in the terminal

The client still wants the physical delivery papers attached to the container when the containers are delivered. For this, human interaction needs to be involved in the transport process. For this to work with automated transport, the client needs to be convinced to get rid of paperwork and digitalize the delivery system. The delivery papers are also sent by mail; these paper documents are used to check which container arrived and if all the goods are in the container. Furthermore, the last-minute changes in the schedule by the client is communicated by telephone. Moreover, at this moment, the container will be left unguarded on their terrain after working hours, which makes it their responsibility, and therefore, the clients do not want the containers to be delivered after working hours. A collaborative digital system should be introduced for CTT Almelo and all clients on the XL Park, where last-minute changes can be picked up by the automated vehicle, reduce manual paper works/ documentation and ensure all the containers are secured. The process flow mentioned in this section is illustrated in the current BPMN diagram (Fig, 4.3) and based on this flow further improvements will be determined in the coming sections.

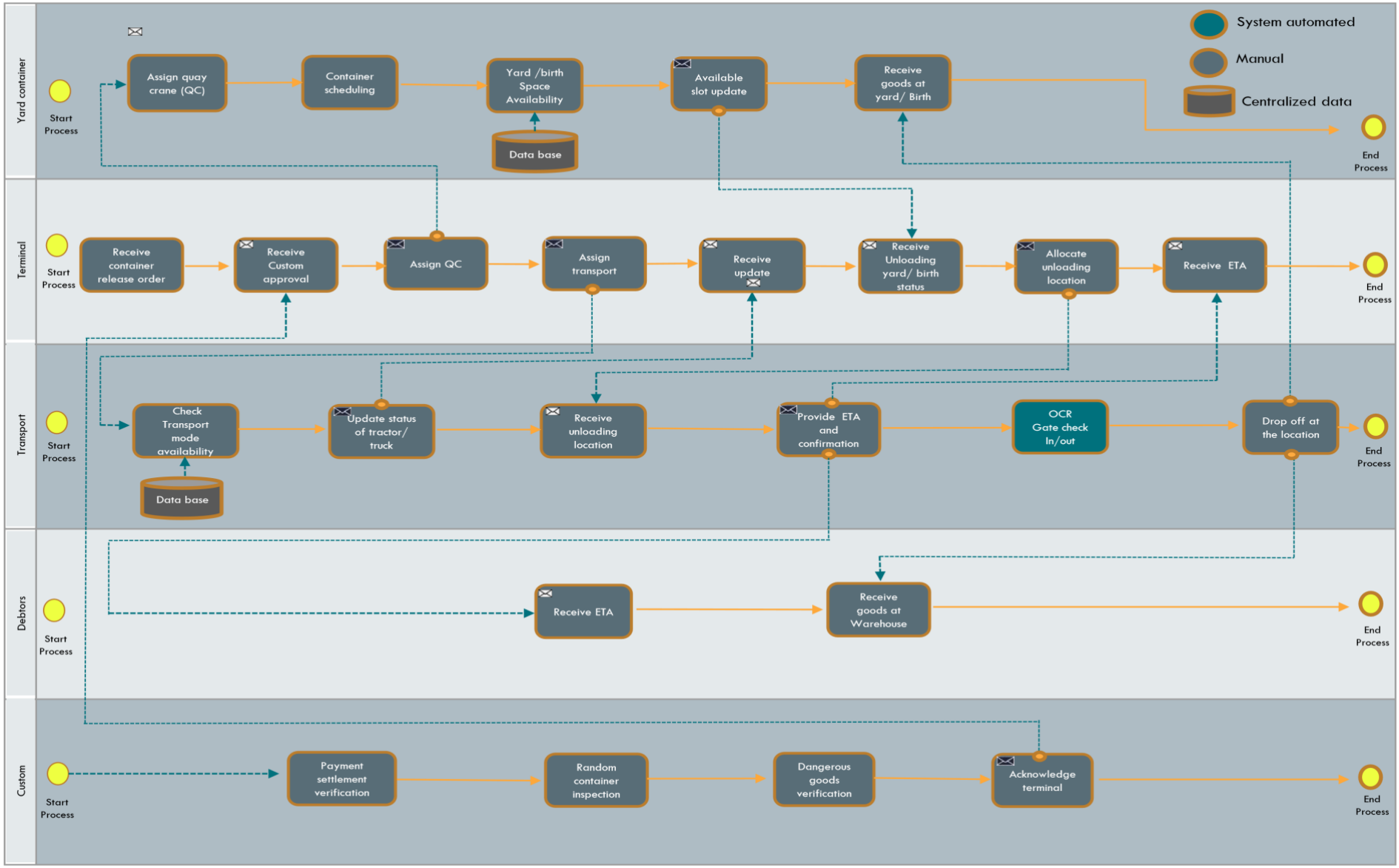


Fig 4.3 Current Process (BPMN)

4.2 Process Bottlenecks and consideration for change

It is vital to consider data privacy, a secured way of interpreting information, minimising operational cost etc., while developing a technical solution which deals with major input related to the shipments. This includes all the documents and the data that is stored and shared among the stakeholders. The terminal operators have both custom compliance requirements to be fulfilled and the need to retain customers trust. Data privacy must be considered eminent when a new system has to be introduced for improving efficiency. However, according to the terminal operators, they are satisfied with the current process as many improvements have been already bought to the system in the past few years.

Meanwhile, in the current process there are still specific processes that are carried out manually, which can be digitalized. According to a research conducted by Mc Kinsey digital on regulated data entry for European banks in the year 2012, it was found that 40 % of entries that were made manually contained errors (Dias, 2020). Furthermore, KPMG found in 2019 that the highest-rated automated improvement in business process is data error reduction (Juttmann, 2019). Moreover, it can always benefit terminal operators and provide real-time data to their valuable stakeholders to build trust and competitive advantage. The current system has the ability only to either receive or send the information making it a one way information system. According to the terminal operators, the change in planning is crucial and cannot be done on short notice period. This shows there is lack of coordination among the actors due to the unavailability of a secured communication system.

All the decisions are made on an organization/network level, and according to the terminal operator, automated technology has more restraint in communicating information within the network. Furthermore, incorporating automation in the planning system can enhance the efficiency of the operation. The potential of implementing autonomous planning is the main reason that makes the terminal operator think AVs on XL Business Park is relevant. This will reduce human intervention on the entire planning process and deliver a smooth and seamless flow of information and collaboration among the stakeholders. Organizations are reluctant to share process data or information to maintain a competitive advantage over similar entities, resulting in a lack of coordination. The clients want the operator to attach the delivery documents physically along with the container while delivering it. Therefore it is necessary to convince the clients to get rid of the paper documents and persuade them to adapt to digital transition. There are areas where transparency can be introduced which will make the information more accessible among the stakeholders and this could be made possible with a decentralised system which blockchain technology can provide. For instance the manual time stamping process mentioned by the terminal operators as a bottleneck can be eliminated by introducing a transparent system. Automation of terminal will reduce the operational cost in the long run and optimize efficient usage of the terminal resources. Furthermore, The monitoring and auditing of all the operations need to be made transparent so that scarce resources can be effectively used.

5. New Business Process using Blockchain technology

In this section, the BPMN for the improved process (Fig 5.3) is explained and the role of using blockchain technology in the unloading process has been determined. In the process of determining smart contract-based applications and related fields, all important data exchanges between stakeholders are determined, followed by real-time business cases, which may be implemented as part of terminal automation through the application of blockchain technology.

Figure 5.1 shows the areas identified in the process flow in which automation can be introduced in terminal operations. There are four major functional areas to be considered in the operations at the terminal and can be classified as container yard operations, customs related formalities, Transport and traffic management. These fields are selected due to its involvement of various stakeholders and complex tasks that requires to be digitalized.

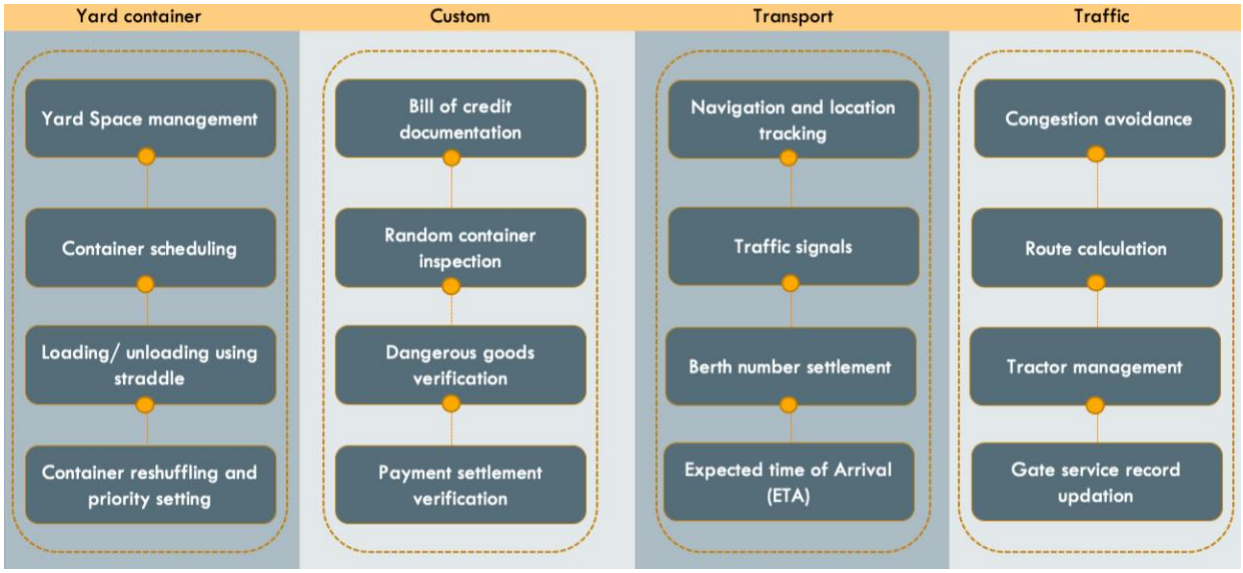


Fig 5.1 Terminal Logistics operations (own composition)

As depicted in the new, improved BPMN (Fig 5.3), most processes are automated by introducing smart contracts for data storage compared to the current process. This allow all the core data stored in the smart contracts to be shared among all the actors involved in the process. Figure 5.2 represents the core data that is being shared to improve the process.

The processes are divided into five sections (A, B, C, D and E) and is depicted in figure 5.3 to simplify the interpretation of the BPMN. The process and the information flow is explained section-wise as follows:

Section A: Contains Cranes data, container data and yard space data that can be stored in the decentralized system to assign them immediately once the custom approval is done. These data can also be used for the maintenance and repair of the equipment. Furthermore, container

details stored in the smart contract will help make the priority-based scheduling and reshuffling of the containers smooth and secure. The allocated space at the berth/ yard is shared among the Debtors and the transporters based on which the transporters can arrange the vehicle. This also gives a competitive advantage since all the information is shared transparently even with the debtors to keep a timely track of the containers. Since smart contracts can securely store such sensitive information, there is no risk of data manipulation.

Section B: The bill of lading documents is accessible to both the shipper and the carrier, allowing hassle-free change of ownership. When changes are made in the documents, all the involved stakeholders receive a notification. Also, information related to the custom document (section E) can be accessed for checking custom approval. Since the operation uses a permissioned blockchain, the access can be authorized based on the requirement. The quay crane is assigned to unload the container and receive unloading location status, and information regarding the ETA is received.

Section C: Once the drop off location is allocated/ received, transport mode is determined from the tractor/ truck data stored using a smart contract which will eventually be shared among all the actors involved in the process. When AV's are introduced at the terminal, it is necessary to simulate the traffic conditions and identify secure routes for transportation. All the data related to the traffic used for simulation can be stored and used to calculate the expected time of arrival and routes. This will give the customers the confidence to receive the exact expected arrival time of the containers in real-time. The current process uses OCR and photographs of the trucks during the gate check-in/ out. However, providing secured and decentralized storage of these data will help monitor them without any manipulation and, if necessary, be shared with other stakeholders.

Section D: The debtors receive all the update regarding the status of the container and transportation details, including custom approval, Yard status, route updates and ETA, in real-time once the container reaches the port terminal.

Section E: All the custom validation documents, such as the payment settlement receipt, bill of credit etc., can be shared during the process using smart contracts. Furthermore, the status regarding the random container inspection and verification of dangerous goods can be accessed by the authorized stakeholders once it is updated in the ledger.

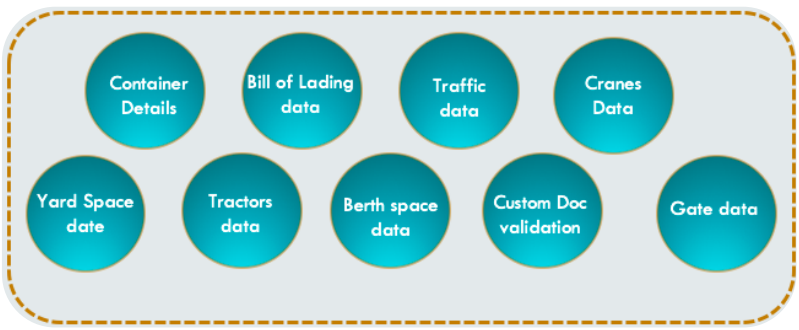


Fig 5.2: Core data shared among stakeholders in the improved process (own composition)

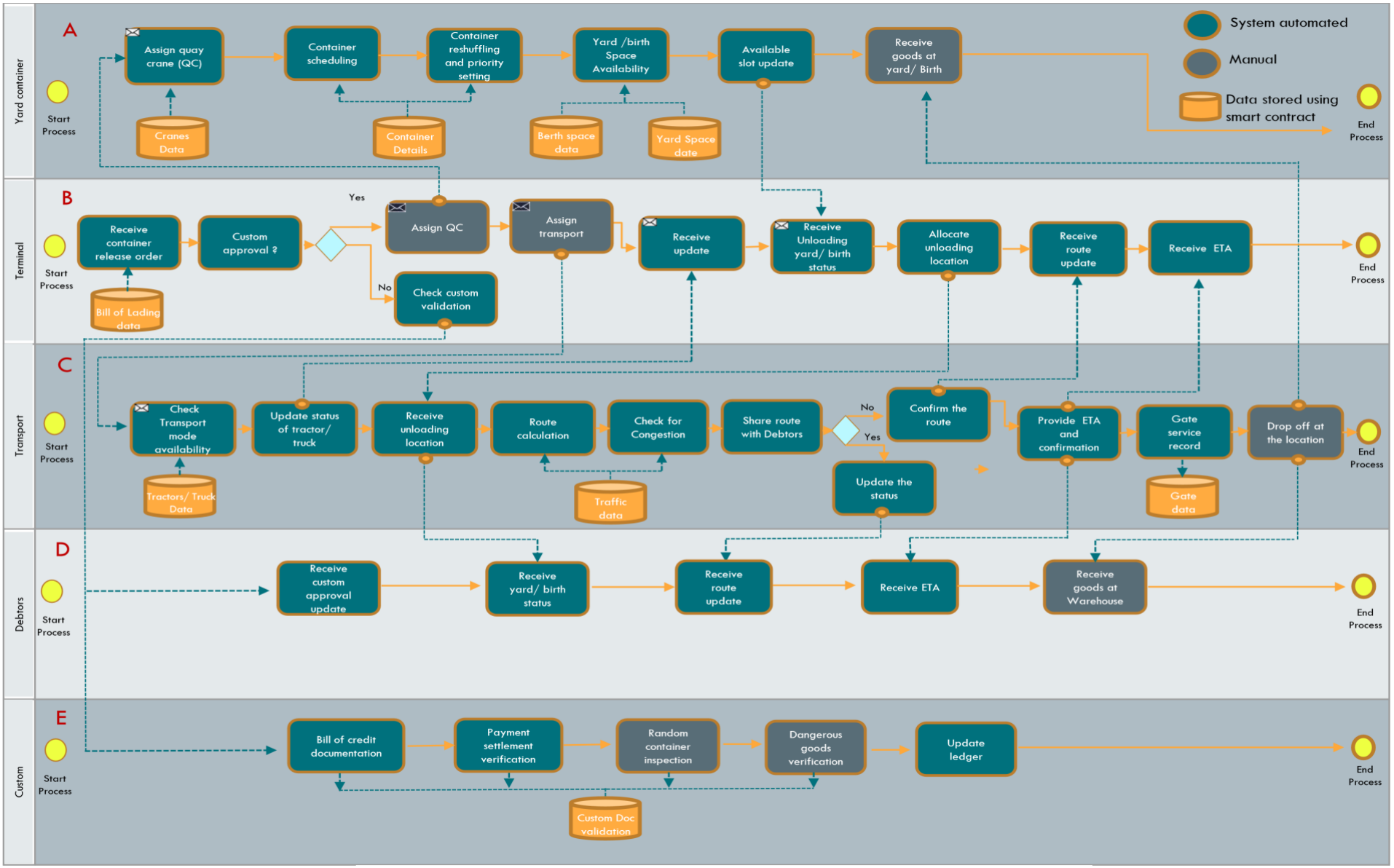


Fig 5.3. New Improved Process (BPMN)

Based on the ongoing process at the terminal the following issues are to be considered with respect to the existing process which could help in exploring the state of the art technology and promoting efficient and competitive working system.

5.1.1 Secured Communication- Release reference number

Current Process bottleneck:

According to Lambert et al. 2008, material flow, financial flow, and information flow are the three flows to be considered for the type of supply chain processes. There is an incorporated financial flow set on port and terminal handling fees, and these rates are processed independently before the process is started. The flow of the material itself is simplified because the container passes through the terminal and loaded on to the truck once it is received through the sea freight. However, the flow of information is not easy. There is a copy of the same data for both the freight forwarder and for the terminal operator. This means that there is duplicate data. The replication hinders the propagation of changes in the release order of the container, such as changing the validation or cancellation of the release order.

Blockchain Use case solution:

The data can be accessed directly through blockchain technology, so there is no need to worry about data transmission. The data is replicated on each node and is the same as on all other nodes. This means the entire EDI application currently in use will no longer be needed. Sharing the same data is quintessential for an efficient supply chain network (Anwar, 2019). The flow of information is either to or from the freight forwarder, transporter, terminal operators etc., using several channels, such as email or telephone or documents. However, blockchain technology promotes a two-way flow of information. The technology can standardize the communication for all the participants on the one hand. On the other hand, the operators can implement an interface that links all stakeholders and access the information (Faith et al.). With the IoT and Physical internet, these decentralized data can be transformed to a human-readable format and shared across all the stakeholders. Furthermore, this also promotes the opportunity of automation in the later stage for all the stakeholders involved in the process

Release reference number and the login ID or truck driver ID card are some of the documents that have to be presented while scheduling or moving a container within the terminal. However, the release reference number is not personalized or encrypted. The release of the container at the terminal can be initiated by any entity who knows or has access to the release reference number. In addition, the terminal only keeps a photographic record of the delivery of each container. Moreover, the container terminal can also try to match the release reference number manually with the number provided by the truck driver. However, this may be considered a slack end because the terminal cannot really determine whether this is the updated custodian of the container to be transported based on the above assumptions. The truck passes through the OCR (Optical Character Recognition), where just a photo is taken, and the container

number and license plate are recorded through text recognition. This situation leads to the uncertainty of ownership and lack of security.

The blockchain technology will allow only ownerships that are assigned with the public key to be custodian at a time. Each stakeholder has at least one public key with a corresponding private key. The public key works as a public address and is recorded with the transactions. (Hackius ,2017). Consequently, the transaction can be initiated by the only owner of the private key. Therefore, the container will only be released by the entity that owns the address's private key. In addition, additional security is achieved to prevent unauthorized access. However, an imposter can acquire the release reference number by tapping on any company's phone communication or email etc. But, in a blockchain solution, it is possible to deceive only when the private key of a single specific entity is confirmed (Hackuis, 2017).

5.1.2 Container sorting – Re-shuffling and priority-based stacking

Current process bottlenecks:

The container terminal continuously sort incoming and outgoing containers and goods in accordance with established norms and rules. For container terminal managers to effectively control multiple operations, they must perform many processing tasks that require professional knowledge and the use of computer systems to make the necessary decisions. The containers are stacked randomly, resulting in several unwanted handling movements to retrieve a container piled below others with a lower priority. In addition, as the height of the stack increases, the complexity to retrieve the container also increases. This is due to a lack of accurate forecasting algorithms, as some parameters are not apparent during the early stage of the process.

Blockchain Use case solution:

A priority-based stacking algorithm is used for yard management at terminals to sort the containers received efficiently (Hasan, 2020). Blockchain technology can use smart contracts along with the potential application of artificial intelligence to efficiently shuffle containers in the yard terminal and enhance resource utilization. The shuffling and stacking algorithms used at the container terminal for sorting the containers highly depend on the data's legitimacy (Hasan, 2020). However, Blockchain technology helps provide an immutable data source, thus eliminating inefficient and incorrect programming due to inaccurate or malicious data. Adopting blockchain technology, in this case, can increase the confidence of consignees, shippers, debtors, and all other major stakeholders due to its potential to increase the visibility and transparency of containers that have to be stacked on a priority base.

5.1.3 Tracking and tracing- Planning route and asset behavior

Current process bottlenecks:

Container terminal equipment such as cranes, straddles, tractor, trucks etc., is such entities that have a great potential of getting automated in the coming years. Furthermore, it could benefit the terminal operators and the stakeholders if they could receive and provide real-time information exchange regarding these entities. The real-time information exchange will increase efficiency and give the debtors and other stakeholders concerned about the shipment's status. Moreover, planning routes and congestion is also a major aspect that has to be considered while automating these transport equipment for its constant and stable functioning.

Blockchain Use case solution:

For intralogistics operations of vehicles, the location of the terminal tractor/ truck stored on the blockchain can be used to simulate and identify potential terminal congestion points (Hasan 2020). Blockchain-based smart contracts can notify terminals of potentially congested areas at the port and can be used to suggest different routes. As crane downtime increases, congestion at the port terminal will reduce productivity. The multi-agent-based system is the most crucial factor of container terminal automation.

Consider installing multiple agents on terminal tractors and cranes. Smart contracts can record these agents and their roles in the blockchain ledger. These agents simulate the role of the custodian to identify and report the behaviour of other carriers or terminal tractors, for instance, increased driving speed or breaking traffic signals etc.

In this case, to access the data to determine misbehaving tractors or carriers, smart contracts can be used (Hasan, 2020). For high accuracy, smart contracts can calculate the average performance of tractors and straddle carriers and use the outcome to minimize the possibility of errors with the application of artificial intelligence (Hasan, 2020). Therefore, with minimum effort and cost, the terminal operators can identify a misbehaving truck or tractor accurately to prevent or minimize terminal accidents.

5.1.4 Trade Documentation- Bill of Lading

Current process bottlenecks:

Accuracy of commercial documents is made sure by the customs official by checking its validity and compliance with travel regulation across the globe. After preparing the logistics documents, they are sent to the recipient through a centralized service system. However, this traditional system of sending documents is costly, slow and has limited credibility. As a result, there will be an increase in the waiting time for containers at the terminal (Francesconi, 2017). Documents that are to be generated include Bill of Lading, customs declaration, letter of credit

and dangerous goods notification. The conventional system face challenges due to the lack of such a database which includes business completion time extension, manipulation of documents, inconsistency in data etc. (Mahwish, 2019).

Blockchain Use case solution:

Blockchain technology can effectively address the above problems and protect business documents through smart contracts and immutable data sources. The technology can potentially provide a unified database to secure real-time access to necessary documents shared during the process by the stakeholders. Therefore, the average waiting time for containers at the terminal can be reduced and eliminate the requirement of manually presenting or sending any documents.

Blockchain technology can guarantee constant visibility and document data integrity among stakeholders to accelerate logistics operations (Juma, 2019). The remaining participants of the supply chain cannot access these documents, by which the privacy of the data is ensured. Furthermore, the customs agents can verify the BoL documents to check if the details specified matches the goods received. Stakeholders of the carrier can generate and approve the bill of lading. Once the BoL is created, the exporter can be notified to check and digitally approve the document with the application of the smart contract. (Mahwish, 2019). The relevant stakeholders who have the access rights will also be notified once the approval is done.

5.1.5 Certification and maintenance

Current process bottlenecks:

All the equipment and vehicles used to transport the containers by the terminal operators, such as quay cranes, straddles, tractor or even trucks, require high maintenance. If not, this will affect the efficiency of the operation and can lead to operational downtime. Furthermore, certification of all these equipment must be up to date; otherwise, the operator must be answerable for the expired and unsafe work equipment during external audits. However, it isn't easy to maintain such crucial information in most cases since it is done manually or just stored in a centralized system. It is necessary to take care of such maintenance procedure seriously to prevent damage to the containers due to equipment failure,

Blockchain use case solution:

Blockchain technology can effectively deal with the above problems by keeping a transparent and immutable record of all movements and ownership changes of cranes or inter-logistics vehicles (Hasan, 2020) . Determining potential failures and identifying uncertified assets can be made possible with the transparency feature of the blockchain technology and can authorize regularities to recognize and audit them.

Furthermore, it is important to perform both scheduled and unscheduled maintenance activities to maintain the vessel's lifecycle. These activities will include Overhaul services, repair, maintaining AMC's (Annual maintenance contracts), etc., of the equipment. Moreover, information such as the service costs, service details, and the schedule for carrying out the service at each intervals can be added to the database created using smart contracts (Hasan, 2020). The blockchain-based transaction logs mentioned above are immutable and can be used to demonstrate the traceability of assets.

5.1.6 Fleet operations management

Terminal automation reduces costs and improves terminal resources; however, in the traditional system, the data related to truck position and speed, mileage etc., is stored in a central server, prone to single points of breakdown. Moreover, the existing system does not provide a system to audit and analyze the tractor/ truck (e.g. fuel economy, parts deterioration etc.) data. Analyzing the fuel consumption rate pattern of the vehicles and part deterioration rate will help the terminal operators and the transporters to change the driving pattern, route, or even driving behaviour.

Blockchain use case:

Fleet management operations are based on multi-objective shared routes to effectively use scarce terminal resources in internal logistics operations to achieve high security, productivity and efficiency (Heilig, 2017). Blockchain technology allows transport vehicles and tractors at the terminal to permanently record and store data such as location, power, weight, fuel consumption rate, mileage, speed and performance data (Hasan, 2020). Moreover, to ensure security and integrity, blockchain-based solutions will digitally sign transactions. These data can be stored and can be made immutable so that routes can be planned without collisions.

Research conducted by Gregorio et al., 2017, analyzed the use capacity of terminal resources through a simulator and checked for blockchain-based solutions to improve the performance of the system. Simulation tools use blockchain-based data to perform more precise, reliable and credible analysis of terminal asset usage. Smart contracts can be used to validate and assist simulation tools in generating profitable routes that are reliable and fast for carriers, tractors and trucks (Hasan, 2020). In addition, smart contracts can manage registered trucks and tractors to decide transportation best suitable for each container. In addition, to ensure spare parts are delivered from reputed manufacturers, ownership details of the spare part can be retained and can be ordered from reputed part providers.

5.2 KPI selection and Evaluation

In this section the key performance indicators relevant to the terminal operation is determined. Key Performance Indicators (KPI) provide businesses with a tool for measuring the

organizations' success. In other words, KPI's can be used to evaluate the performance of specific products or processes. These indicators allow to analyze the current state and demonstrate the progress of performance when evaluated regularly.The business use cases identified in the previous section will be evaluated with the KPI's identified in table 5.1 and these KPI's are determined reviewing available literature with a case study approach. Furthermore, a framework is created to evaluate the use cases of the technology with respect to the KPI's and validation of this framework is done by conducting interview.

	Key Performance Indicators	Description
Operational	Intermodal terminal throughput (volume) (Hinkka, 2018)	Amount of trucks, Tractors, straddles the terminal handles over time
	Equipment utilization (Hinkka, 2018)	Use and performance of the asset at the terminal, reduction in cost of equipment in the long run
	Gate utilization (Hinkka, 2018)	Number of gate moves you complete per day (in and out)
	Container Traffic (Hinkka, 2018)	Amount of container traffic going through at terminal at any given time
	Storage area utilization (Hinkka, 2018)	Berth and yard space utilization : number of locations typically used to the total locations committed to a given lot
	Container dwell time (Hinkka, 2018)	Time a container stays at the port terminal
Ω Information	Security in information sharing (Fransisconi, 2017)	Measures the security of the mean of communication, in terms of information access and information sharing.
	Access speed to information (Fransisconi, 2017)	Speed in receiving or accessing the information needed at the right time in the process
	Accuracy of information regarding status of shipment (Fransisconi, 2017)	Measures whether the parties involved in the process have access to correct and accurate information on the shipment.
	Provision of on-time updates of cargo information (Fransisconi, 2017)	Availability of updated information on the cargo

Financial	Freight bill Accuracy (Fransisconi, 2017)	Estimation of the number of errors in freight billing, which include incorrect pricing, incorrect or unavailable information, etc
	Overall cost of information flow of a unit of cargo (Fransisconi, 2017)	Measures the Inter-organisational information system performance in terms of information flow total cost.
	Average cost of demurrage (Hinkka, 2018)	Amount of container's demurrage or detention in the port in terms of costs. These phenomena are the proof of delays in payments or paperwork unavailability and errors
	Maintenance cost of Equipment's	Cost incurred in corrective and preventive maintenance
Environmenta	Energy consumption (Hinkka, 2018)	Amount of energy utilized for handling a container
	Carbon footprint per unit. (Hinkka, 2018)	Amount of Co2 Emitted during the operation of a container

Table 5.1 KPI selection and description

Key Performance Indicators (KPI) provide businesses with a tool for measuring the organizations' success. In other words, KPI's can be used to evaluate the performance of specific products or processes. These indicators allow to analyze the current state and demonstrate the progress of performance when evaluated regularly. They are mostly used for benchmarking, setting targets, monitoring, and decision making when ranking is concerned.

An extended investigation of terminal's performance benefits terminal operators/ managers to make decisions efficiently. The knowledge of terminal performance indicators can increase transparency and can attract more debtors by building a competitive advantage compared to other service providers. Therefore, KPI's can be considered a diagnostic tool that will help in continuous improvement by demonstrating areas of improvement (Hinkka, 2018). Moreover, information related to the performance indicators will allow terminal managers to understand better and consider multiple stakeholder views and manage relations with them.

In this research, 16 performance indicators have been identified to evaluate the performance of the terminal. These indicators are categorized into four divisions: operational, Information, Financial, and environmental indicators. The analysis is an effort to explain the impact of blockchain technology solutions identified in section 4.3. Therefore, each business solution is evaluated with respect to the defined KPI's based on which its impact can be determined and validated.

6. Validation of the improved process and the solutions.

6.1 Interview Methodology

To evaluate the blockchain solutions, interviews were carried out and followed a semi-structured set up to assist the conversation and ensure enough flexibility in addressing the issues and getting insights from the respective experts. The interviews were conducted through Microsoft teams and were held in English. Participants were requested to consent to the use of gathered research materials. The interviews were conducted in two different stages; the first stage was to acquire information regarding the process and the operations at the Port terminal and the second stage was to evaluate the new business process. First, the Terminal operators were interviewed and based on which the bottlenecks were determined (Section 4.1.1, 4.1.2, 4.2). Then, the second stage of the interviews are conducted to evaluate the blockchain applications identified specifically for terminal operations to digitalize the existing process.

The second stage of the interview is to analyze the unexplored impact of blockchain application in the terminal operation. The investigation of this research will not include any hypothesis or preconceived notion and, therefore, is carried out in an inductive set-up rather than a deductive study. During the interview, the participants were allowed to elaborate upon the applications to understand the practicality in implementing it in real-time circumstances. This approach will allow understanding the perspective of different actors involved in the process, starting from the developers to the end-users. Therefore, three different views are considered to evaluate the application and understand the perspective on implementing it, and they are the blockchain experts/ developers (TNO, Blocklabs, Siemens), Research institutes (Windesheim applied research institute), Port authority (Twente), and container terminal (Combi Terminal Twente).

The interview composed of exploratory and open-ended questions, which made the discussion more interactive and insightful. The respondents were given a brief explanation of the BPMN depicting the current and the new process after the implementation. They were asked to evaluate the flow in the process based on the determined applications of blockchain technology. Furthermore, the implications and limitations of implementing these applications were addressed in real-time situations, and the KPIs' significance were evaluated. The discussions were held on the basis of the improved process that can be implemented with the application of blockchain Technology. The applications and the improved processes (BPMN) were demonstrated in the discussion and were thoroughly checked with the experts. The recommendations given by the experts can be considered when implementing a blockchain based system and for further studies.

6.2 Discussion

Major insights and feedbacks received from the blockchain and the logistics experts through interviews related to all the solutions are explained in this section. In SME's like CTT, there could arise difficulties during its expansion in allocating the resources to accommodate more debtors or customers due to predicaments in sharing information. However, in this research, based on the available literature, it is evident that the blockchain technology can timely allocate transportation resources in a secured manner. Implementing such technology can effectively reduce waiting time for the containers and increase the throughput volume by employing more efficient transportation systems. Furthermore, the real-time communication between the stakeholders to share the information and the timestamps can make the process more flexible and cost-effective. An application like smart contracts allows the terminal to store data, publish them within the network, and be monitored regularly. However, the technology is in its initial stage. It is crucial to concede the perspective of different actors who are experts in their respective fields associated with Logistics and blockchain development. During the interview, the respondents were asked about the implication of implementing such disruptive technology to surmise the benefit, actuality and barriers. The following table describes the details and the background of the interviewees who have supported validating the applications identified. The details of the interviewees are mentioned in the following table (Table 6.1).

Category	Interviewee	Organization	Function
Supply Chain Expert	Sebastian Piest	Port of Twente (Netherlands)	Principal researcher at University of Twente, Represents Port of Twente -collaborating with industries and universities.
Container Terminal Manager	Danny Otter	Combi Terminal Twente (Netherlands)	Operations Manager – Process improvement and innovation
Blockchain and smart contract expert	Victor Van Der Hulst	Windesheim University of Applied Science (Netherlands)	Program manager- Supply chain Finance professorship, Innovation consultant, Project Manager- Spark Living Lab
Blockchain Engineer	Wout Frijters	Blocklab (Netherlands)	Blockchain developer, Mechanical Engineer.
Blockchain Engineer	Erik de Graaf	TNO (Netherlands)	Software developer, Scientist innovator

Table 6.1 Details of the interviewees

The respondents collectively validated the blockchain's potential functionality in terminal operations to secure information sharing within the network. The applications identified in the research were discussed with the blockchain developers and experts to understand the real-time difficulties and significance of implementing them. The respondents had expertise in developing real-time blockchain applications in the field of technology, logistics, energy etc. The interview lasted for a minimum of 45 minutes to maximum of one hour. The following sections explains briefly the discussion related to each blockchain use case solution and the significance of those application on the KPI's.

Fig 6.1 Steps for determining blockchain use case requirement in any process (based on interview)

6.2.1 Use case solution – Secure release reference number

The first application shared among the respondents was the duplication of reference number identified in section 5.1.1. The situation at the terminal was explained to the respondents where the transporter comes to pick up the container, and the transporter has to authenticate to avoid any kind of deception. As explained in Section 4.1.2, the current process collects the OCR data to authenticate the transporter. However, by using blockchain technology, the process of authentication could be made more secure.

According to the blockchain developers, this application could be used more of an additional registration or a security layer in this particular situation, rather than entirely relying on it. Blockchain is more suitable when events have to be timestamped in a secured manner on a shared network. Smart contracts can be developed where the private keys can be whitelisted for the entrance to the terminal and can be authenticated. Furthermore, once entered in the smart contracts, the timestamps cannot be changed since they are immutable, making it more reliable. According to the blockchain experts, this could be done completely offline by signing the message with the private key at the terminal for accessing the entry. However, the terminal must know the public key of the transporter, which is registered in the blockchain. Another interesting approach suggested by a respondent to tackle such issue without the public and the private keys using blockchain is by using tokens, and it's called "Secured container release", where the driver of the truck holds the token, which is used to identify himself to get the right container loaded on the truck. Currently, all the movement of the containers at the Port terminal are considered secured according to the port authority and the terminal operator compared to a few years back by already introducing the Optical character recognition system. However, in the coming years, the terminal's ongoing automation process will need such a system that only blockchain technology could provide to secure the container movement.

6.2.2 Use case solution – Container reshuffling and priority setting

The second application discussed where regarding the reshuffling and priority based setting of the containers (Section 5.1.1). The containers are stacked randomly, leading to several undesired movements, and as the height of the stack increases, it makes it more difficult to retrieve containers that have high priority. It depends on high legitimacy of data and blockchain technology can provide the immutable data source.

According to the respondents, to improve this particular issue the blockchain can be used as a transparent data store, for instance, storing the container data and the order of the container, making it visible to all the stakeholders. However, according to the logistics expert, this problem could be solved without the application of blockchain just by capturing the container details while it passes the OCR gate. But, if there is any case of damage and the information or damage report has to be shared with the respective stakeholders, in that case, blockchain can be of use. Furthermore, a respondent suggested considering blockchain application for reefer container for perishable goods (temperature-controlled containers). There are several information related to the position, temperature, humidity , authorized opening / closing of the door etc of the container which has to be monitored. So the locks can be stored in the blockchain and can be shared throughout the chain. This could avoid the dispute among the actors involved in the process in case of goods expiry etc.

6.2.3 Use case solution – Tracking and Tracing

The real-time information exchange can enhance efficiency and provide the customers and other stakeholders concerned about the shipment's status (Section 5.1.2). Moreover, according to the literature, route planning and congestion data can also be acquired through vehicle Ad - Hoc network (VANET) (Javaid, 2019). The equipment sharing the information receives incentives, and this can be made possible using the blockchain. However, this use case was discussed with the developers and logistics experts to validate its relevance. According to the logistics expert, this will be useful if it is organised in a park level (XL Businesspark), but to implement it in the private environment, for instance, just for CTT, wouldn't be beneficial.

Another instance where the tracking application discussed was to track the behavior of the assets such as the trucks, cranes and all modes of transportation involved in the process. When the situation was explained to the experts they identified, the application has a scope to be implemented since multiple actors/ companies will be involved in providing different modes of transportation during the phase of terminal expansion. Therefore, there could be trust issues due to multiple agents and blockchain technology has the potential to tackle such trust issue. However, the respondents also pointed out the challenge associated with implementing such system as it is equally important to convince all the current stakeholders to join the initiative. Moreover, the experts also implicated that it is difficult to store a lot of data in smart contracts due to a lack of space/ capacity. Nevertheless, it could work well if the entire data is stored in

the traditional database, and the hash of the required information can be linked to the data set to acquire it.

6.2.4 Use case solution – Bill of Lading

International trade needs supply chain actors to manually fill out and submit various paper documents to move goods across boundaries. The respondents forecast the availability of unified data provided by blockchain technology to ensure access to documents by the actors in real-time. Currently, the terminal lacks this unified database. The availability of real-time data in the supply chain can significantly enhance the speed of the logistics process. Technically, the secure hash is adopted and supported by a consensus algorithm to achieve this with blockchain technology. Therefore, attempts to change the information in the commercial document are detected and reported immediately. For example, the Bill of Lading is recorded and can be accessed by only relevant stakeholders such as custom agencies, delivery agents, cargo agents, bank agents, etc.(employing a Private blockchain platform).

Moreover, the most prominent development and Proof of Concepts the experts working on are digitalizing documentation such as import documents, transporting documents, BoL, etc., in different fields using the technology to obtain the entire information flow. According to the blockchain developers, digitalizing trade documentation can be considered as a starting point for applying blockchain technology in the logistics sector. However, there are certain consequences related to the technology since the technology is in its initial stage, and companies are still finding difficulties in accepting the value blockchain could contribute. Therefore it is vital to improving the flexibility and the scalability for successful adoption of the technology.

6.2.5 Use case solution - Certification and Fleet management.

According to a blockchain developer, when implementing the blockchain solution, it is important to identify where in the process there is a trust issue. The terminals need to maintain the annual maintenance and calibration of all the equipment. The respondents were asked the significance of using blockchain technology in getting notifications when it is time for maintenance. It was identified that there is a trust issue when it comes to maintenance since different service providers are involved in the process and therefore, blockchain application has the potential in tackling such trust issues. Perhaps, the spare parts also can be ordered from a credible vendor based on its service history stored in the smart contract. However, the best suitable approach would be using a digital twin of the asset and Non Fungible Tokens (NFT) for this situation according to a respondent. NFT's are a unique token of blockchains that are not exchangeable. Therefore, for instance, the trucks license plate can be tokenised with these unique tokens. With these tokens it is possible to add data related to the specific vehicle. Furthermore, the ownership of the assets can be exchanged just with these tokens. A respondent emphasised on also including the events such as accidents to be registered in the system during

the fleet operations since there could be a conflict of interest as the truck driver doesn't want the authority to know about the mis happening. This will help the Terminal operator market themselves by building a transparent system by revealing all accidents registered in the blockchain system. This could build trust in the debtors, and they can easily verify the credibility of the terminal operators.

6.3. Success Factor of BC and alternative solutions.

In this section, the critical evaluation of blockchain compared to alternative solutions will be carried out. Despite its potential, blockchain adoption has been delayed beyond proof of concept. The comparatively slow performance of early blockchain technology has been a significant concern. The earliest blockchain networks could only process a few transactions per second and may take up to an hour to ensure transaction legitimacy. There are several blockchain alternatives that are more performant. Businesses may also want to think about them if they wish to cut expenses, streamline development, and eliminate integration issues. Alternatives to the blockchain is a bit backward, given blockchain itself is an alternative. The actual challenge is discovering new methods to disintermediate the intermediary and reimagine business processes, regardless of whether blockchain provides the means. Cloud storage and distributed databases, for example, give some of blockchain's data integrity and dependability benefits while posing less performance, efficiency, and cost concerns. The table below (Table 6.2) compares the parameters of alternative technologies concerning Blockchain technology

Available Technologies	Cost	Cyber security	Reliability and data integrity	Scalability
Blockchain				
Centralized databases				
Distributed Ledgers				

Table 6.2 Comparison of blockchain with alternative solutions

One of the most severe issues regarding conventional blockchains, as seen in Table 8.1, has been scalability. Furthermore, decentralization adds cost by its very nature in keeping numerous copies of data and assuring consistency. Blockchains also come with a lot of computing requirements and energy consumption issues. Thus, while the blockchain community may be enthusiastic about decentralizing the database, there is real value in maintaining a centralized database with a single well efficient system of record.

According to the Trend Insight Report from research company Gartner (Kandaswamy, 2020), just 10% of businesses would accomplish any dramatic change utilizing blockchain by 2022.

In addition, by 2022, at least one breakthrough blockchain-based firm will be valued at $10 billion. Furthermore, the business value generated by blockchain is expected to reach slightly over $360 billion by 2026 and more than $3.1 trillion by 2030. However, although newer blockchain implementations are improving, they still fall short of what can be accomplished with a well-managed centralized database. One of the most enticing aspects of Blockchain has been its ability to improve security. On the other hand, Enterprises may continue to utilize blockchain alternatives to secure transactions, improve product tracking, facilitate product recalls, safeguard privacy, and preserve audit trails. Blockchain is sometimes marketed as a decentralized data storage system but comes at a higher cost. Cloud services' trust, security policies and governance levels, according to industry analysts, are sufficient for most corporate applications (Lawton,2021). Furthermore, numerous third-party data storage providers can provide greater governance and security for a fraction of the cost of a blockchain. Nonetheless, because Blockchain is a new technology, opinions on its potential are varied.

Another potential area for blockchain technology's future growth is cybersecurity. Data tampering is a persistent problem for organizations of all sizes. Blockchain technology may be used to prevent data tampering and allow parties to verify the validity of a file. However, Blockchain technology is still in its infancy and has a long way to go before it is widely used. We don't know how effective it will be in everyday use by the general public or which blockchain variant would function best. While there are some advantages to alternatives to Blockchain, there is yet no clear-cut superior version of blockchain technology. Nevertheless, let's assume blockchain technology will have a comparable impact on the world in the future years as the internet did in the 1990s and early 2000s.

6.3.1 Selection criteria of blockchain and alternative solution

Blockchain is only required when a group of unknown people wishes to achieve an agreement. However, blockchain might be utilized in any situation where a database is required, and therefore all the application identified during the analysis in Section 5 of this research paper has the potential to be implemented in the future. This might lead to the concept of public permissioned blockchains and private permissioned blockchains, both of which are essentially shared databases. The alternative solutions listed in Table 6.2, on the other hand, do not have the same restrictions as blockchain. In reality, these technologies have been thoroughly tested throughout time and have been shown to deliver the necessary functionality. If a specific party's functionality has to be controlled, a common central database can be utilized. Setting rules for how database permissions are set (such as create, store, and remove) or saving data in the database are examples of controlling database functioning.

Another alternative technology is the distributed database, such as the cloud storage network, which might be utilized if no transaction interaction is necessary. If transaction interaction is necessary, participants are identified, for example, by a certificate authority, and anybody can join the network; a distributed ledger might be utilized again. "Ripple" is an example of a non-blockchain application that employs a distributed consensus ledger with a network of validating

servers and crypto tokens rather than blockchain (Lawton, 2021). Furthermore, a distributed ledger can be utilized even when access restriction is in place; for example, the program "Corda" does not group together transactions that need confirmation into a block and confirm them all at once. Corda, on the other hand, certifies each transaction in real-time (Lawton, 2021). In theory, a blockchain might be utilized in these situations. However, other technologies, on the other hand, exist that do not have the same disadvantages as blockchain. Blockchains are frequently sufficient but not always essential, and this is especially true in the case of public blockchains. If the players are unknown, blockchain may be a viable option. At the moment, blockchain's ability to process a high number of transactions is restricted. It is unsuitable for storing huge volumes of transactional data. Despite the fact that current scalability research has demonstrated considerable advances, there are presently no global implementations. The application described in this study may be implemented using either centralized, distributed, or blockchain technologies. However, in order to select the best technology, it is also necessary to examine the value that various technologies may bring. Future research might assess the real-time benefits and drawbacks of selecting the best appropriate technology in the same way

6.4 Blockchain application and its significance to proposed KPI's

In this section based on the KPI's, a framework is built (table 6.3) to evaluate the impact of the Blockchain solutions. A qualitative approach is used due to the lack of quantitative data representing the operation or performance. The significance of each case of the blockchain solution is depicted in the table. However, the impact of these applications on the KPIs are validated based on interviews with various stakeholders associated with the terminal operation and blockchain experts working on developing the technology.

All the KPI's identified are particularly for improving terminal operations. The table combines two axes: the X-axis representing the applications identified in the study and the Y-axis denoting the key performance indicators identified in Table 5.1. The relevance of each business case solution of blockchain technology is evaluated subjectively concerning the KPI's to determine the impact of implementing it. Furthermore, the table is divided into four categories: operational, information, financial and Environmental.

The KPI's from each category with the highest significance is determined. From the table, we can infer that equipment utilization has the highest impact on the acceptance of blockchain solutions in the operational category. Therefore if the applications are introduced in the system, there could be a reduction in the cost of equipment in the long run due to the effective use and performance of the asset at the terminal. In the second category (information), two KPI's has been identified with the highest impact, i.e. security in information sharing and access speed to information. Hence, blockchain technology can provide high security in accessing and sharing information with a greater speed once implemented. Furthermore, in the third category, the most impacted KPI is the overall cost of information flow of a unit cargo. This implies that the terminal could save the cost incurred in setting up information flow at the inter-

organizational level. Lastly, in the environmental category, the implementation of blockchain applications can impact energy consumption rate and reduce the emission rate which is produced during the operation of a container.

	Key Performance Indicators	Secured communication	Container sorting	Tracking/ tracing	Trade Documentation	Certification/ Maintenance	Fleet Management
Operational	Intermodal terminal throughput (volume)			●			
	Equipment utilization		●	●			●
	Gate utilization	●					●
	Container Traffic			●			
	Storage area utilization		●				
	Container dwell time		●		●		
Information	Security in information sharing	●	●	●	●	●	●
	Access speed to information	●	●	●	●	●	●
	Accuracy of information regarding status of shipment		●	●	●	●	
	Provision of on-time updates of cargo information		●		●	●	
Financial	Freight bill Accuracy	●			●		
	Overall cost of information flow of a unit of cargo	●	●	●	●	●	●
	Average cost of demurrage	●			●		
	Maintenance cost of Equipment's					●	●
Environmental	Energy consumption		●	●			●
	Carbon footprint per unit		●	●			●

Table 6.3 Framework for evaluating the business use cases of blockchain

7. Roadmap to implementation

In this section the roadmap for implementing the identified solutions is described with a timeline approach. Blockchain can be considered as a disruptive technology viewing its long term scope and applications in container transportation. However, it will take at least 4 to 5 years for any IT transformation to take place. Moreover, with the changing market need and the landscape, it is challenging to forecast for a period beyond that. (Krizner, 2018). The blockchain hype started in 2018 in various industries, and slowly, most enterprises are in the phase of finding ways to exploit the technology by working on prototypes and proof of concepts. Furthermore, according to Kriznar et al, 2018 , the implementation plan of the blockchain technology can be divided into three categories; Technology, Service and Market. The figure 7.1 illustrates the roadmap for implementing Blockchain technology in terminal operations.

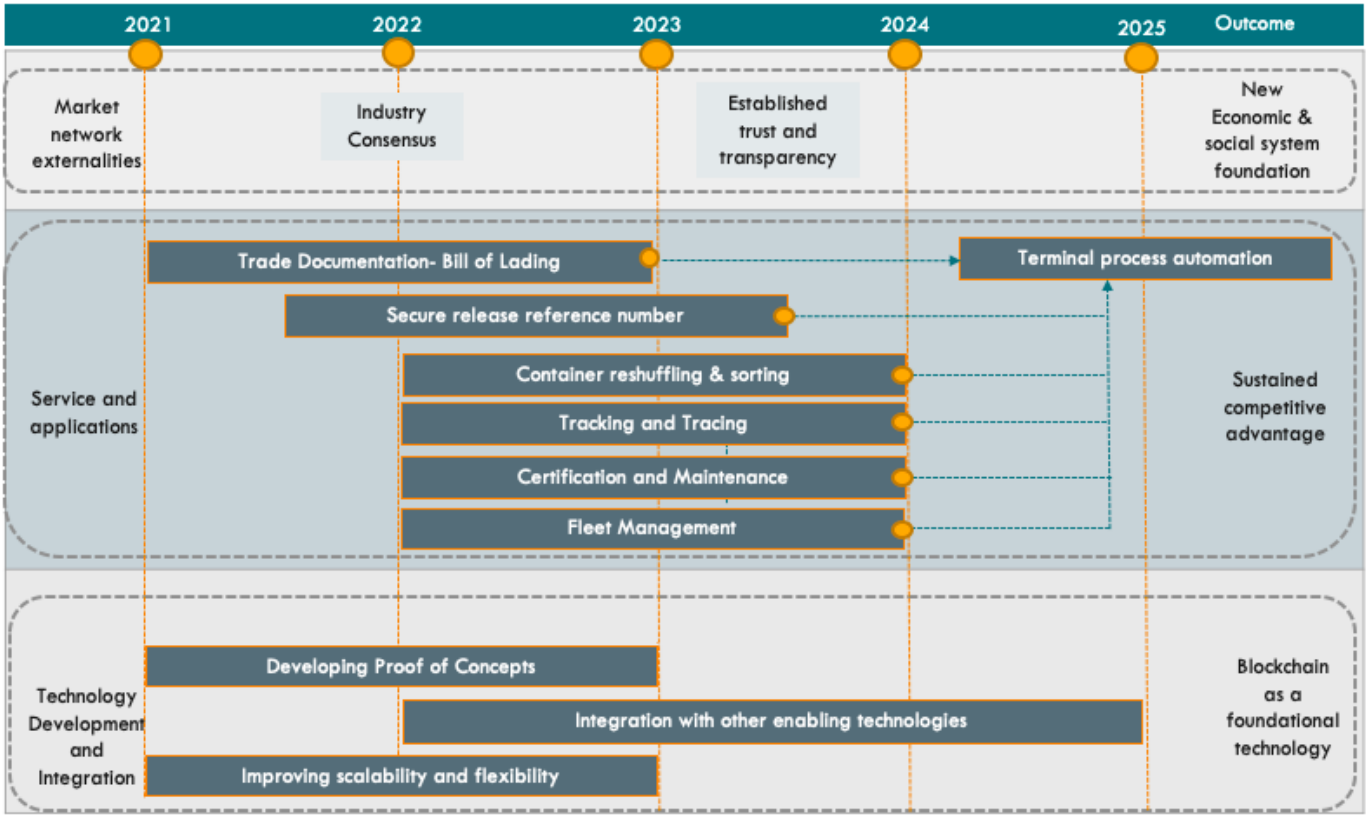


Fig 7.1 Implementation roadmap

7.1 Market network externalities

Three major milestones are to be considered in this section: industry consensus, trust and transparency, and finally, standardization of the process. In a competitive environment, the market needs a set of solution regardless of the fact that any technology can offer it or not. The standardized process of the technology can possibly happen in the coming five years. Moreover, the blockchain developers are already working on digitalizing the bill of lading documentation. This application has comparatively the highest scope of getting implemented in the first place due to the pace at which the developers are

working to implement it and due to the availability of literature and research on this topic. However, it is essential to convince all the stakeholders to bring a decentralized system into practice. The realization of transparency and increased trust in the terminal operation depends on whether the industry collectively agrees on common goals using such decentralized technology. The companies involved in the process have to stress the advancement of blockchain technology within inter-level operations to adopt the technology successfully. The formation of such an alliance can propagate collaboration through such state of the art technology. Furthermore, it is essential to develop data standards throughout the system to make the automation process efficient. Therefore, the responsibility of the actors, the vision and the consensus of the industry has to be defined cearly for achieving this roadmap in the coming years. All the related actors should come on board and be part of the drives to implement the technology on a vast scale. However, this can be achieved by considering everyone's interests involved in the process by equalizing the benefit and avoiding any violation of standards.

7.2 Service and application

The applications identified in this research that are either proof of concepts or under development are placed on the middle lane of the timeline. These applications are listed based on their current level of development. This is determined through interviews with blockchain developers/ experts and based on available market applications. It was identified that most of the developers are already working on solutions to decentralize the trade documentation process (Bill Of Lading). Therefore, this application has a high scope of getting implemented in the industry compared to other applications.

Furthermore, reshuffling and sorting of the containers can also be executed with the application of blockchain technology due to its immutable characteristics, increasing data legitimacy. During the interview, the experts mentioned that the secured communication to avoid duplication of a release reference number has the possibility to be implemented once the technology is established and the organization is looking for ways to improve competitive advantage. Furthermore, the implementation of Tracking of vehicles, penalty setting for misbehaving equipment, certification and fleet management is highly dependent on the integration of Blockchain with other enabling technologies such as IoT and AI.

7.3 Technology development and integration

The industries should be willing to test the applications of blockchain technology to attain its value to its full potential. Therefore it is vital to support start-ups that come up with disruptive solutions to the market. There are many start-ups already working on PoC's as a part of automating various operational levels. Furthermore, to sustain this, there should be continuous improvement in the flexibility and scalability of the technology. However, the maturity level of the technology is still low. Hence, it is crucial to maintain the scalability and flexibility to increase the confidence in adopting the technology to convince the stakeholders. Furthermore, once these aspects are bought into action, the technology can be integrated with other technologies such as IoT, AI, Physical Internet, Cloud computing etc. (Sec 7.3). This integration could enable extended applications of the technology to decentralize and automate the system with more security and reliability..

8. Conclusion and Recommendation

A closer look at the terminal operations and the use case application of blockchain technology to automate those operations is made in this study. This research could be considered for reporting an initial recitation and potential implications of implementing a blockchain-based solution in Port-terminal operations for hub-to-hub transportation. The study presented suitable blockchain applications specific to the terminal operations through onsite visits, literature and interviews. It was found that the experts consider the decentralizing and unifying the flow of information has a potential advantage as it could bring more effectiveness to the system, make the process more transparent and eliminate duplication. However, it was also found that such a level of transparency could also become a barrier due to the hesitancy of the actors involved in the process to share data. The study compares the current business process with an improved blockchain-based process by employing BPMN. The contribution made in the study can possibly help the researchers and the developers to introduce Proof of concepts and different business models. The real-time implication in the research is limited; however, it is expedient for companies to engage in field testing and case studies to recognize whether they can benefit from implementing the technology for enhancing the information flow. Overall, the blockchain technology holds high possibilities concerning process optimization, with the likelihood of being employed across the whole logistics chain. However, Blockchains are often sufficient but not often necessary and particularly If participants are unknown, then blockchain may provide a solution.

It can be concluded from the study that blockchain it is a assuring technology that can hold both the digitalization of the terminal and improve the efficiency of the whole information flow. Nevertheless, to make this happen there are certain hurdles to be cleared. Firstly, the company must certainly understand the benefits of blockchain technology and decide whether it is really a necessity for them to have a blockchain database. As identified in the interview (fig 6.1), they must determine the major events and try to identify the trust issues and conflict of interest for employing a blockchain solution. Secondly, it is vital to understand the pros and cons of using the blockchain-based system. It is also important to consider alternative IT systems as well to support the functioning of blockchain technology. It is advisable to invest in the technology on a low complexity level in the initial stage and further expansions could be made on the later stages based on the size of the network.

The mindset of the current actors in the Logistics sector must change for successful implementation of the technology. It is vital to make sure all the stakeholders interested in the automation process are on the same direction. Trust among the stakeholders is one of the critical issues identified, resisting them from joining hands to implement such decentralized technology since the reputation of the companies providing the data plays a significant role. Therefore it is necessary to make sure and convince all the involved parties that they can rely on the data provided by the blockchain system. In this situation, the role of the XL Business park and the port authorities becomes essential as they can take on the role of facilitator and convince all the major players and addressing the concerns mentioned above to implement a

decentralized system for increasing overall efficiency. Furthermore, they could standardize the system by coordinating and integrating blockchain applications. Taking such responsibility will help bring all the stakeholders under the same roof and initiate a transition path for digitalizing the operations.

9. Research Limitations

Blockchain technology currently is at the peak of the hype cycle and there is only limited information regarding the technology. It is still unclear whether the technology will succeed if applied or create any impact on organizations. Besides, most of the literature and the PoC's presented has only mentioned the technology's positive sides. There are majorly two challenges identified when the technology is studied as an emerging IT technology. First, there is no explicit confirmation on the innovative feature of blockchain technology since the technology is a combination of already existing or established technologies. Secondly, technology is closely intervened with strong social values and ideology. Therefore, using the business model determined in practice is complex and needs an acceptable simplification.

Furthermore, there are several limitations linked to the empirical part of this research that needs to be regarded due to the exploratory characteristics of the research. First, secondary data were majorly considered for the identification of the business case solutions. For increasing the validity of the analysis, it is vital to add primary data. However, due to the time constraint, it was not possible. The analysis and the interpretation part of the models were highly reliant on the researchers understanding of the blockchain domain. The credibility of the improved business process should be further evaluated. This research was only conceptually evaluated in the form of discussions with qualified experts and researchers in the logistics and blockchain development domain. Finally, it was challenging to reflect on the interview results with the industry experts since they had a very diverse background and perspective on the technology.

10. Future research scope

Based on the findings of this research and on its limitation, new directions for future research are proposed. It is necessary to be further test the credibility of the proposed methodology in the future. For instance, similar studies could be made so that the results could be compared to come up with a more accurate and reliable analysis. Moreover, this research only focuses on the terminal operations; similarly, other industries can also be investigated with such kinds of explorative studies, and the implications of implementing the blockchain technology can be determined effectively and compared. This can help in giving a better understanding of the blockchain-enabled business processes and based on which new applications can be introduced. Tokenization with blockchain technology has a great potential in Logistics operations. Therefore studying the role of tokenization and its impact on the business process has ample scope for future studies.

This research paper's objective can be considered a base for future studies related to blockchain applications in the field of Logistics and terminal automation. A multitude of research opportunities can arise from this research paper. Only a limited part of several applications that has the potential to be developed in the future is represented in this paper. However, this research could be considered as a starting point for conducting quantitative studies to evaluate the impact of the technology and develop implementation strategies.

From a scientific perspective, the goal of this research was to build a solid base for further blockchain literature in the field of logistics: a general overview on the topic on which further research can be developed upon. Therefore, there is a multitude of research directions that arise from this study. This section discusses the most important ones. Furthermore, the evaluation was done only with a limited sample of respondents for this research due to time constraints. However, future studies could be carried out with broader samples and further inspect its validity in different terminals located at various locations. Furthermore, in the implementation roadmap (Fig 7.1.), the bottom part of the roadmap illustrated in the analysis, depicted as "Technology development and integration", provides a very general overview of blockchain development. Future research could improve parts of the blockchain adoption roadmap by researching and adding milestones of blockchain development itself.

11. Contribution as a Management of Technology thesis.

The master thesis project should be assessed using certain criteria that is mentioned in the assessment guidelines. The faculty's graduation requirements state that the thesis must contain an analytical component, be multidisciplinary, and focus on a technical domain or application. Furthermore, graduates in Management of Technology should comprehend how organizations can use technology to their advantage to improve their performance qualitatively or statistically. This paper attempted to comprehend, investigate, and assess blockchain technology in the context of a specific business operation. In addition, the thesis also offered advice on the technology's future implementation.

The dissertation presents a scientific investigation in a technical setting, demonstrate the corporate perspective of technology, and demonstrate its comprehension using scientific methods and procedures learned during the studies. There was an analytical component to the thesis. The classification of the study into multiple elements has aided in delineating the problem and reaching deductive conclusions. To accomplish this, the research objective was divided into multiple research questions, and the research framework described in Chapter 6 was followed. The majority of the scientific methodologies and procedures utilized in the thesis were covered in numerous classes during the Management of Technology master's program. The thesis was difficult not just because of the technology's novelty but also because the practical problem had to be thoroughly examined.

The research has been shown to be interdisciplinary since it spanned multiple disciplines and needed knowledge of a technology that evolved from the fields of information technology and concepts from logistics management and business process management to map, analyze, and re-design business processes. Furthermore, a special emphasis was placed on the use of blockchain as a technology in certain logistics operations, with a corporate perspective on the technology. The technology was comprehended and presented in layman's terms, with the primary goal of debunking it and determining its potential solutions.

12. Bibliography

Astarita, V. (2020). *A Review of Blockchain-Based Systems in Transportation*. MDPI. https://www.mdpi.com/2078-2489/11/1/21

Baalen, N. (2009, October 18). *now publishers - Port Inter-Organizational Information Systems: Capabilities to Service Global Supply Chains*. NOW. https://www.nowpublishers.com/article/Details/TOM-008

Bagloee, S. A., Tavana, M., & Withers, G. (2019, December 1). *Tradable mobility permit with Bitcoin and Ethereum â "A Blockchain application in transportation*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S2542660519302240

Barrett, S. (1982). *JSTOR: Access Check*. JSTOR. https://www.jstor.org/stable/248993?casa_token=QoO_JsmEkcgAAAAA%3AKgFp-TExwzTyq1jLTWMm3DMX3rag15Nc4WppAtpSFBT-dgRro3pZk2rAERGz0SOAeCH4q9fz3l4vV9DELuI46Sis1R2QQdmwO1I9sXkDkfo_aqR-izic&seq=1#metadata_info_tab_contents

Böse, J. W. (2011). *Handbook of Terminal Planning | JÃ¼rgen W. BÃ¶se | Springer*. Springer.https://www.springer.com/gp/book/9781461428213#otherversion=9781441984074

Castelein, B., Geerlings, H., & Duin, R. (2020, September 15). *Cold Chain Strategies For Seaports: Towards a Worldwide Policy Classification and Analysis*. ResearchGate. https://www.researchgate.net/publication/344493551_Cold_Chain_Strategies_For_Seaports_Towards_a_Worldwide_Policy_Classification_and_Analysis

Dorri, A., Steger, M., & Kanhere, S. (2017, December 1). *BlockChain: A Distributed Solution to Automotive Security and Privacy - IEEE Journals & Magazine*. IEEE. https://ieeexplore.ieee.org/document/8198814

Drever, E. (2003). Using Semi-structured Interviews in Small-scale Research: A Teacher's Guide. Scottish Council for Research in Education. Retried from: https://books.google.nl/books?id=MV2ZAQAACAAJ

European Commission. (2016, September 22). *Road*. Mobility and Transport - European Commission. https://ec.europa.eu/transport/themes/its/road_it

Fridgen, G. (2019). *Opportunities and Challenges of DLT (Blockchain) in Mobility and Logistics - Fridgen Gilbert*. ORBI Lu. https://orbilu.uni.lu/handle/10993/44503

Garud, R., Tuertscher, P., & Ven, A. H. (2013, June 1). *Perspectives on Innovation Processes*. ResearchGate.

https://www.researchgate.net/publication/236132885_Perspectives_on_Innovation_Processes

Haralambides, H. (2017, April 20). *Globalization, public sector reform, and the role of ports in international supply chains*. Maritime Economics & Logistics. https://link.springer.com/article/10.1057/s41278-017-0068-6?error=cookies_not_supported&code=26bc95a9-72b9-4fb7-af3e-9eb65096b5ba

Huber, S. (2015, September 28). *Consideration of transport logistics hubs in freight transport demand models*. European Transport Research Review. https://link.springer.com/article/10.1007/s12544-015-0181-5?error=cookies_not_supported&code=1fd7236d-4f0a-4ca3-8d30-16db1aeefc51

Janic, M. (2007, January 1). *Modelling the full costs of an intermodal and road freight transport network*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S1361920906000794?casa_token=v21st3F0N_gAAAAA:wJn2OxKEU0S7p3UdrDJdZbx9mLAdMj3yR-KYagKb58StuFoTkj5HzheS54RSQ8R0PLs1I10LCFo

Javaid, U., Aman, M. N., & Sikdar, B. (2019, April 1). *DrivMan: Driving Trust Management and Data Sharing in VANETs with Blockchain and Smart Contracts - IEEE Conference Publication*. IEEE. https://ieeexplore.ieee.org/document/8746499

Jiang, L. (2018, December 12). *Breaking Blockchain — A Framework to Evaluate Blockchain Use Cases*. Hacker Noon. https://hackernoon.com/breaking-blockchain-a-framework-to-evaluate-blockchain-use-cases-9efbc30a3fa7

Johnston, H. R. (1988). *Creating Competitive Advantage with Interorganizational Information Systems | Semantic Scholar*. Semantic Scholar. https://www.semanticscholar.org/paper/Creating-Competitive-Advantage-with-Information-Johnston-Vitale/954d924fba44e219a9912ca3723c76b1006406ef

Kim, S. (2017, July 24). *Intelligent Vehicle-Trust Point: Reward based Intelligent Vehicle Communication using Blockchain*. ArXiv.Org. https://arxiv.org/abs/1707.07442

Knirsch, F., Unterweger, A., & Engel, D. (2017, September 4). *Privacy-preserving blockchain-based electric vehicle charging with dynamic tariff decisions*. SICS Software-Intensive Cyber-Physical Systems. https://link.springer.com/article/10.1007/s00450-017-0348-5?error=cookies_not_supported&code=0242c166-239e-43c5-88b1-25bc1c513d1e

Lei, A., Cruickshank, H., Cao, Y., & Asuquo, P. (2017, December 1). *Blockchain-Based Dynamic Key Management for Heterogeneous Intelligent Transportation Systems - IEEE Journals & Magazine*. IEEE. https://ieeexplore.ieee.org/document/8010820

Lu, R., Lin, X., & Shen, X. (2017, March 1). *SPRING: A Social-based Privacy-preserving Packet Forwarding Protocol for Vehicular Delay Tolerant Networks - IEEE Conference Publication*. IEEE. https://ieeexplore.ieee.org/document/5462161

Merkas, Z., & Perkov, D. (2018). *The Significance of Blockchain Technology in Digital Transformation of Logistics and Transportation | IGI Global*. IGI Global. https://www.igi-global.com/gateway/article/240732#pnlRecommendationForm

Nakasumi, M. (2017). *Information Sharing for Supply Chain Management Based on Block Chain Technology | Semantic Scholar*. Semantic Scholar. https://www.semanticscholar.org/paper/Information-Sharing-for-Supply-Chain-Management-on-Nakasumi/954fd7af3bc53719c0c681d5aad9706c553ed96e

Newman, N. (2018, July 1). *IET Digital Library: Can blockchain transform transport?* IET Digital Library. https://digital-library.theiet.org/content/journals/10.1049/et.2018.0605

Pienaar, W. J. (2008, November 2). *Tshwane logistics hub : an integration of freight transport infrastructure*. Sun Scholar Research Repository. http://scholar.sun.ac.za/handle/10019.1/2656

Pustisek, M. (2016). *Blockchain Based Autonomous Selection of Electric Vehicle Charging Station | Semantic Scholar*. IEEE. https://www.semanticscholar.org/paper/Blockchain-Based-Autonomous-Selection-of-Electric-Pustisek-Kos/c3034826eea18996d324b80f7aed6e86da7cfdc9

Remco, M. (2008, November 1). *Semantics and analysis of business process models in BPMN*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0950584908000323?casa_token=8q-csDJbWgQAAAAA:0zK_RdHPxF_sGPbZbpbFOZaqr3rqKmG8T0eR4Mti-j_QbFVtzPblT-7wc8usCRPJRd0RZBTZwUI

Rushton, A. (2014). *The handbook of logistics and distribution management : understanding the supply chain, 5th edition (eBook, 2014) [WorldCat.org]*. WorldCat. https://www.worldcat.org/title/handbook-of-logistics-and-distribution-management-understanding-the-supply-chain-5th-edition/oclc/872429842

Saunders, M. (2019). *Saunders, Research Methods for Business Students, 8/E*. Pearson. https://www.pearson.com/nl/en_NL/higher-education/subject-catalogue/business-and-management/Research-methods-for-business-students-8e-saunders.html

Singh, P. K. (2019, June 24). *Smart Contract Based Decentralized Parking Management in ITS*. SpringerLink. https://link.springer.com/chapter/10.1007/978-3-030-22482-0_6

Subramani, M. (2004). *JSTOR: Access Check*. JSTOR. https://www.jstor.org/stable/25148624?casa_token=ZjkPiJgPhT4AAAAA%3AjIoxwQ1ZgOrNUikka5kFh44h45mEw8k1sdscGCIJjg-fo4cLO_zMcDBlOWDeSNHuI5-sxQIUIxoZ13dqrMP_EQ5iOc9r_5J2wLGVN8-GpXgpUCvuo_-g&seq=1#metadata_info_tab_contents

Tasca, P., & Tessone, C. J. (2019, February 15). *A Taxonomy of Blockchain Technologies: Principles of Identification and Classification*. ResearchGate. https://www.researchgate.net/publication/331145523_A_Taxonomy_of_Blockchain_Technologies_Principles_of_Identification_and_Classification

Tijan, E. (2019). *Blockchain Technology Implementation in Logistics*. MDPI. https://www.mdpi.com/2071-1050/11/4/1185

Weber, I. (2016, September 18). *Untrusted Business Process Monitoring and Execution Using Blockchain*. SpringerLink. https://link.springer.com/chapter/10.1007/978-3-319-45348-4_19

Wilson, D. (1998). *Interorganizational information system technology and buyerâ€• seller relationships | Semantic Scholar*. Semantic Scholar. https://www.semanticscholar.org/paper/Interorganizational-information-system-technology-Wilson-Vlosky/eb9c971c19a35832463c618d04607c41aeaf0e3f

Woo, S. (2013). *An assessment of the integration of seaports into supply chains using a structural equation model -ORCA*. ORCA. http://orca.cf.ac.uk/47875/

Wu, H. (2017). *A Distributed Ledger for Supply Chain Physical Distribution Visibility †*. MDPI. https://www.mdpi.com/2078-2489/8/4/137

Yang, Y.-T., Chou, L.-D., Tseng, C.-W., & Tseng, F.-H. (2019). *Blockchain-Based Traffic Event Validation and Trust Verification for VANETs*. IEEE Journals & Magazine. https://ieeexplore.ieee.org/document/8663370

Yuan, Y., & Wang, F. Y. (2016a, November 1). *Towards blockchain-based intelligent transportation systems - IEEE Conference Publication*. IEEE. https://ieeexplore.ieee.org/document/7795984

Yuan, Y., & Wang, F.-Y. (2016b, November 1). *Towards blockchain-based intelligent transportation systems - IEEE Conference Publication*. IEEE. https://ieeexplore.ieee.org/document/7795984

Anwar, M. (2019a). *Digitalization in Container Terminal Logistics: A Literature Review*. DIVA. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1337559&dswid=3504

Anwar, M. (2019b). *The feasibility of Blockchain solutions in the maritime industry*. DIVA. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1337565&dswid=193

Bavassano, G., Ferrari, C., & Tei, A. (2020, January 15). *Blockchain: How shipping industry is dealing with the ultimate technological leap*. ResearchGate. https://www.researchgate.net/publication/338601763_Blockchain_How_shipping_industry_is_dealing_with_the_ultimate_technological_leap

Buck, W. (2021, March 10). *Step by step towards a digital port.* Port of Rotterdam. https://www.portofrotterdam.com/en/port-forward/step-by-step-towards-a-digital-port

Chowdhury, M. (2007). *SAGE Journals: Your gateway to world-class research journals*. SAGE Journals. https://journals.sagepub.com/action/cookieAbsent?casa_token=sp7FIu83_eYAAAAA:FJJlo5si7BQ7cweeolZMfagpLrTmrP92Uf_PMPIYFIyTGe9XlAogTwtAsr1K1LaIChUwnvG23nbXZw

Francisconi, M. (2017). *An explorative study on blockchain technology in application to port logistics | TU Delft Repositories*. TU Delft. https://repository.tudelft.nl/islandora/object/uuid:b1de98dd-f1a7-456a-b8cb-4d87dc2c4f9f

Gregorio, R., & Nustad, S. (2017, November 15). *Blockchain Adoption in the Shipping Industry: A study of adoption likelihood and scenario-based. . .* ResearchGate. https://www.researchgate.net/publication/323292747_Blockchain_Adoption_in_the_Shipping_Industry_A_study_of_adoption_likelihood_and_scenario-based_opportunities_and_risks_for_IT_service_providers

Guo, X. (2012, January 31). *Dynamic space and time partitioning for yard crane workload management in container terminals*. TRID. https://trid.trb.org/view/1133757

Hartvanyi, T., DSc, K. L. T., Németh, P., & Tóth, L. (2005, January 1). *Architecture of Intelligent Intermodal Logistics Centres*. ResearchGate. https://www.researchgate.net/publication/295077571_Architecture_of_Intelligent_Intermodal_Logistics_Centres

Hasan, H. (2021, February 2). *Blockchain applications and architectures for port operations and logistics management*. ScienceDirect.

https://www.sciencedirect.com/science/article/abs/pii/S2210539521000031?via%3Dihub

Heilig, L. (2017a, October 1). *Multi-objective inter-terminal truck routing*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S1366554517301709

Heilig, L. (2017b, December 16). *Digital transformation in maritime ports: analysis and a game theoretic framework*. NETNOMICS: Economic Research and Electronic Networking. https://link.springer.com/article/10.1007/s11066-017-9122-x?error=cookies_not_supported&code=305fbefb-95a1-47d7-bd24-f45e3f71da72

Henesey, L., & Anwar, M. (2019a, September 1). *Development of state-of-the-art on BlockChain in Small Ports*. ResearchGate. https://www.researchgate.net/publication/336701906_Development_of_state-of-the-art_on_BlockChain_in_Small_Ports

Henesey, L., & Anwar, M. (2019b, September 1). *Development of state-of-the-art on BlockChain in Small Ports*. ResearchGate. https://www.researchgate.net/publication/336701906_Development_of_state-of-the-art_on_BlockChain_in_Small_Ports

Imai, A. (2005, March 1). *Berth allocation in a container port: using a continuous location space approach*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0191261504000505?casa_token=HOW8HLCzzu4AAAAA:Ko8zh98jKsWFHjb_J60SvvjuW8n0dIJ1XjP80oJg_X-3fIVlhlF9qS_OYRy-7z_Aa12AGqmZkPg

Juma, H. (2019). *A Survey on Using Blockchain in Trade Supply Chain Solutions*. IEEE Journals & Magazine | IEEE Xplore. https://ieeexplore.ieee.org/document/8936386

Juttmann, J., & Raan, K. (2019, January 25). *Manage the effects of Robotic Process Automation to enable a future-proof workforce*. KPMG. https://home.kpmg/nl/nl/home/insights/2019/01/manage-the-effects-of-rpa-to-enable-a-future-proof-workforce.html

Kandaswamy, R. (2020). *Blockchain-Based Transformation: A Gartner Trend Insight Report*. Gartner. https://www.gartner.com/en/doc/3869696-blockchain-based-transformation-a-gartner-trend-insight-report

Lambert, D. (2008). *The Supply Chain Management and Logistics Controversy | Emerald Insight*. Emarald Insight. https://www.emerald.com/insight/content/doi/10.1108/9780080435930-007/full/html

Lawton, G. (2021, May 25). *6 alternatives to blockchain for businesses to consider*. SearchCIO. https://searchcio.techtarget.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider

Lokuge, P., & Alahakoon, D. (2007, March 1). *Improving the adaptability in automated vessel scheduling in container ports using intelligent software agents*. ResearchGate. https://www.researchgate.net/publication/222116614_Improving_the_adaptability_in_automated_vessel_scheduling_in_container_ports_using_intelligent_software_agents

Meyer, T. (2019, October 1). *Blockchain technology enabling the Physical Internet: A synergetic application framework*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0360835219303973

Rida, M. (2006, December 16). *Object oriented model for container terminal distributed simulation*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0377221705002341?casa_token=84by4QYY9y4AAAAA:OwqyBPMiDLixBJ927CmafTNyeFtjiz_hi8RehPeVm-B9KKVVTQGAejcCbHhTsTXBSPyTMYwkHnE

Treiblmaier, H. (2019). *Combining Blockchain Technology and the Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management*. MDPI. https://www.mdpi.com/2305-6290/3/1/10

Tsertou, A., Amditis, A., Latsa, E., Kanellopoulos, I., & Kotras, M. (2016, December 31). *Dynamic and Synchromodal Container Consolidation: The Cloud Computing Enabler*. ResearchGate. https://www.researchgate.net/publication/304530073_Dynamic_and_Synchromodal_Container_Consolidation_The_Cloud_Computing_Enabler

Yang, X. (2019). *SG11202002734S MANAGING BLOCKCHAIN-BASED CENTRALIZED LEDGER SYSTEMS*. WIPO. https://patentscope.wipo.int/search/pt/detail.jsf;jsessionid=667F3AAAB2A23495E1C541D13CADD41F.wapp1nA?docId=SG294402981&_cid=P10-KDMUHK-83534-24