TOWARDS AUTOMATED CONTAINER TRANSPORTATION BY INTEGRATING BLOCKCHAIN TECHNOLOGY: A CASE STUDY AT XL BUSINESSPARK IN ALMELO

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Abstract

The application of blockchain has great potential in the logistics industry, especially in because transportation involves multiple actors and a considerable numbers of transactions. This paper presents the results and findings of case study research at XL Businesspark as part of the STEERS project and adds 6 use cases for blockchain technology solutions in logistics to the body of knowledge. The application of blockchain is investigated in-depth at Combi Terminal Twente to automate terminal processes, support future applications of connected automated container transport and streamline communication with warehouse facilities. The results of this case study and use cases will be further developed and prototyped in the Spark! Livinglab.

1. Introduction

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. Blockchain is an emerging technology with numerous applications in different industries. Blockchain could help to connect many players and handoffs within the regime of bringing efficiency to the many detached elements. There are multiple companies testing blockchain solutions to solve issues, ranging from data processing to fleet management. The application of blockchain has great potential in the logistics industry, especially because transportation involves multiple actors and considerable numbers of transactions associated with the supply chain. Nowadays, companies need to do more than just keeping the track of products leaving the production unit or the arrival at the warehouse. In order to meet customer expectations, 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 global supply chain. The logistics service provider needs to grant access to information systems and there is often a lack of direct access at the intra-organization level since this process is 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 (Merkaš et al., 2020). Intelligent transportation could benefit novel technologies such as blockchain. It 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 sectors and most importantly collaboration of various stakeholders. The logistics sector is growing and the demand for expanding existing distribution centers/terminals is increasing as well as the need for automating the processes at both existing and new locations. All terminals face continuously new challenges in meeting transport growth rates while the capacity of infrastructure stagnates (Castelein et al. 2019). With regard to information access or information communication, the current practice at terminals faces problems in multiple areas. These problems are lack of communication and limited data sharing between stakeholders, lack of predictability of the traffic situation (Böse 2017), including unknown trucks arrival times, difficulty to consider mixed traffic conditions 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 and access to data only from designated location via on premise local system.

This paper aims at finding solutions to problems arising during the transformation phase towards an automated container transportation system with the application of blockchain by making it more transparent and sustainable compared to the conventional approach. This paper is based on the master thesis project of Suraj Dharmasastha (Dharmasastha, 2021).

2. Case study: Port of Twente

Port of Twente connects transporters and companies with the most dynamic main ports in the Eastern part of the Netherlands. The Port of Twente is one of the biggest inland ports of the Netherlands. Combi Terminal Twente (CTT) and multiple Logistics Facilities (see Figure 1) are situated at XL Businesspark in Almelo. CTT has its own storage and transshipment terminals in Hengelo, Almelo and Rotterdam and offers synchromodal transport with the possibilities of water, freight rail and container transport by road. The management 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 and due to modal shift the demand for transportation is increasing. Therefore the terminal's infrastructure needs to be optimized in the next few years. As a result, more automated systems are already implemented in the facilities to enhance efficiency, including intelligent gates and advanced access control systems. Automated terminal trucking for hub-to-hub logistics is part of CTT's roadmap towards the physical internet to achieve in the coming years to remain sustainable and have a competitive advantage over other terminals.

Figure 1. Illustration of XL Businesspark and major hubs at Almelo.

The ambitions of Port of Twente and logistics partners are aligned together in a project called STEERS (Towards intelligent interhub logistics). STEERS is a public-private collaboration between CTT , Bolk Transport, the University of Twente, Hogeschool Arnhem & Nijmegen, Hogeschool Rotterdam, XL Businesspark and Regio Twente. STEERS is a feasibility study 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 automated transport technology to address such challenges. The main aim of STEERS is to investigate the requirements for the application of automated guided vehicles for 'business park transportation' and simultaneously explores the potential of intelligent hub-to-hub transport (STEERS, 2021). This paper 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 guided vehicle in inter hub transportation.

3. Current Processes at CTT Terminal Almelo

Once a vessel arrives at the port, the physical 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 the storage yards. When the tractor reaches the destination point at the yard, the yard crane starts unloading the container from the tractor and stores it in a specific block in the yard.
A container is 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 when returning the operator checks if there is an empty container available to take back to the terminal.
The client still wants to receive the physical BoL attached to the container when the containers are delivered. For this, human interaction is still needed. The BoLs are also sent by mail; these 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 are communicated by telephone. Moreover, at this moment, the container will be left unguarded on their terrain after working hours, which makes it their responsibility as the clients do not want the containers to be delivered after working hours. It is necessary condition that the processes need to be digitalised/automated in order to introduce AGVs. The digital system allows last-minute changes that can be picked up by the automated vehicles and a reduction of manual paper works/ documentation to secure all containers.

4. Use Cases for Blockchain Technology Solutions

Use case 1: Secured Communication- Release reference number

According to (Lambert, 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, although simplified, is related to the container movement through the terminal and truck transport between the warehouses. However, the flow of information such as agreements are exchanged before, is not straight forward.

Process bottlenecks: In the current situation there is a copy of the same data for both the freight forwarder, the terminal operator, container trucking company and receiver. 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. 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 personalized by a driver card and a biometric scan of the driver's hand. 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) gate, where the container number and license plate are recorded through text recognition. Still this situation can lead to the uncertainty of ownership and lack of security.

Blockchain 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 essential for an efficient supply chain network. 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 (electronic) 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. With the IoT and Physical internet, the decentralized data can be transformed 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. 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. In a blockchain solution, it is possible to deceive only when the private key of a single specific entity is confirmed (Hackius, 2017).

Use case 2: Container sorting – Re-shuffling and priority-based stacking

The container terminal continuously sorts 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.

Process bottlenecks: 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. The stack planning is based on experience and is not on auditable and transparent.

Blockchain solution: A priority-based stacking algorithm is used for yard management at terminals to sort the containers received efficiently (Ahmad et al., 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 (Ahmad et al., 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 and specific handling instructions.

Use case 3: Tracking and tracing- Planning route and asset behavior

Container terminal equipment such as cranes, straddles, tractor, trucks etc., are 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.

Process bottlenecks: At this moment this type of information exchange is not available. 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. Avoiding congestion and inefficiencies of the equipment are hard to foresee.

Blockchain 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 (Ahmad et al. 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. This should be seen in line with the development of a multi-agent system. 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 (Ahmad et al., 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 (Ahmad et al., 2020). Therefore, with minimum effort and cost, the terminal operators can identify a misbehaving truck or tractor accurately to prevent or minimize terminal accidents.

Use case 4: Trade Documentation- Bill of Lading (BoL)

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.

Process bottlenecks: 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 BoL, 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 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 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 BoL. 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.

Use case 5: Certification and maintenance

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 responsible for the expired and unsafe work equipment during external audits.

Process bottlenecks: 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, or the maintenance is in control of the supplier. It is necessary to take care of such maintenance procedure seriously to prevent damage to the containers due to equipment failure.

Blockchain 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 (Ahmad et al., 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 annual maintenance contracts 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 (Ahmad et al., 2020). The blockchain logs the transactions mentioned above immutable and can be used to demonstrate the traceability of assets. Furthermore, this use case provides a foundation for predictive maintenance applications.

Use case 6: Fleet operations management

Terminal automation reduces costs and improves terminal resources.

Process bottlenecks: 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 analyse the tractor and/or truck (e.g. fuel economy, parts deterioration etc.) data. Analysing 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 solution: 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 (Ahmad et al., 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), analysed 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 (Ahmad et al., 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. Conclusions

It can be concluded from the case study that blockchain is an assuring technology that can hold both the digitalization of the terminal and improve the efficiency of the whole information flow. This paper adds 6 use cases for blockchain technology solutions in logistics to the body of knowledge. Nevertheless, to make this happen there are certain hurdles to be cleared. Firstly, the company and involved supply chain partners must certainly understand the concepts, use cases, benefits and risks of blockchain technology and decide whether it is really a necessity for them to have a blockchain. 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. Secondly, it is vital to identify the trust issues and potential conflicts of interest for employing a blockchain solution.

The mindset of the current actors in the Logistics sector must change for successful implementation of the technology. It is crucial 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 Businesspark and the port authorities becomes essential as they can take on the role of neutral facilitator, 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. The results of this case study and use cases will be further developed and prototyped in the Spark! Livinglab.

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