Blockchain technology integration in vehicle dealer inventory management system

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Abstract of the Master's thesis

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Abstract

Presently the Volvo Group Trucks Operations (GTO) supply chain network is designed in such a way that there is no traceability at the individual spare part level. As industrial digitization has become a necessity, especially for the supply chain network, the Volvo group has taken the initiative to explore new technologies in order to align themselves with the modern digital age of business.

In the past few years blockchain technology applications, especially in the supply chain sector, have seen an enormous interest both from the industrial sector and academic sector. Thus it was decided to explore Blockchain technology to design a proof-of-concept in the dealer inventory management which has contributed in defining the primary objective of this master thesis.

The primary objective of this master thesis was the design of a proof-of-concept for integrating blockchain technology in the reverse logistics process at Volvo GTO, especially for the North European market. Along with the proof-of-concept, various challenges and opportunities for Volvo GTO as a service provider in the domain of Blockchain technology integration and Dealer inventory management are presented in this master thesis.

Keywords Blockchain technology, Dealer inventory management, Logistic Partnership Agreement – LPA, Reverse logistics, supply chain traceability and transparency

Preface

I would like to start by thanking my manager Mr. Rosin Laurent, senior manager DIM and Mrs. Liljenberg Lina for giving me this opportunity to work in the area of Blockchain technology and operations management.

I would like to thank my immediate industrial supervisor's namely Mr. Chandrasekaran Sureshkumar and Mr. Ljunggren Fabian, my academic supervisor Dr. Robert John Millar from Aalto University, Finland and academic advisor Dr. Jagruti R Thakur from KTH Royal Institute of Technology, Sweden - Without their valuable insights, guidance and support, I would have not been able to successfully complete my Master thesis work.

I would also like to thank Mr. Sjögren Sebastian for his constant support and guidance and Mr. Maldaner Pedro for helping me with data extraction from various Volvo GTO IT systems.

Otaniemi, 11.12.2019

Adithya Haribabu Vangar

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Abbreviations

1. Volvo GTO: Volvo Group Trucks Operations
2. DIM: Dealer Inventory Management
3. LPA: Logistic Partnership Agreement
4. RFID: Radio frequency identification
5. QR Code: Quick Response Code

Chapter 1.
Introduction

1.1 Problem discussion

Presently the Volvo Group Trucks Operations (GTO) supply chain network is designed in such a way that there is no traceability at the individual spare part level. As industrial digitization has become a necessity, especially for the supply chain network, Volvo group has taken the initiative to explore new technologies in order to align themselves with the modern digital age of business. Blockchain technology was chosen to be explored further especially for a reverse logistic process called the ´Buy-back´ process.

At Volvo Group there are various teams working towards the maintenance and planning of the supply chain network. One of these functions is the dealer inventory management. Here Volvo Group has an automated process called the Logistic Partnership Agreement – LPA for the restocking and refilling the dealer facility with new and healthy Volvo spare parts in a periodic manner. Once the dealer agrees to the Logistics Partnership Agreement, Volvo Group as a service provider will periodically restock and replace the dealer facility inventory. Here as a goodwill gesture, Volvo Group gives a complete 100 % buyback guarantee to all the spare parts stock volumes which have not been sold out, become outdated or expired. The dealer is credited with the present day price for all the spare parts stock volume covered in the buyback process. As this is a cost intensive process for Volvo Group, traceability of genuine Volvo spare parts across the supply chain network is highly desired.

1.2 Thesis purpose / Objectives

1. To evaluate if blockchain technology can be integrated with the Volvo Group Trucks Operation (GTO), especially with the segment of Dealer Inventory Management (DIM) on the supply chain network. In order to secure traceability of genuine Volvo parts, regardless of how and where the parts have been purchased and distributed.
2. To understand the current operations management at DIM team, especially for the ´Buyback´ process and review how blockchain technology could be applicable.
3. Desired output is to have a proof of concept showing the possible impact on the Buyback process, traceability at individual part level and transparency on the supply chain network.

1.3 Thesis limitations

Flow of value in the form of cryptocurrency is a limitation, which affects the close Loop operation of the smart contracts. No exploration and research has been carried out with regards to the financial regulations and policy.

As the primary objective of this thesis is the design and development of Proof of Concept, the inculcation of financial transactions is not of prime importance.

1.4 Acknowledgments

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Chapter 2.
Background

2.1 Blockchain technology

Cryptocurrencies can be defined as digital currency which uses cryptographic techniques in order to generate currency units along with simultaneously securing their transactions. In recent years we have seen an exponential increase in the domain of cryptocurrencies, although the research on cryptocurrency dates back to the1980´s. The first electronic cash system was proposed by Chaum [22]. Despite extensive research e.g., [23] [24], there was little success in the development of a cryptocurrency that could be used by people in day-to-day transactions. This scenario drastically changed with the invention of Bitcoin [25], which uses distributed ledger technology known as blockchain. During the month of December 2017, when the value of one Bitcoin skyrocketed to approximately 20,000 USD, the underlying technology of Bitcoin cryptocurrency went viral. Many engineers and innovators across the world started exploring applications where Blockchain technology could be used to bridge a gap in the market and create value. As per the recent reports by CoinMarketCap [30], the total blockchain market is expected to grow from 411 million USD in 2017 to 7683 million in the next five years. What makes blockchain applications promising is its nature to make trusted third party intervention in a business process redundant.

One of the domains where blockchain technology fits-in perfectly as an underlying technology is supply chain management. This thesis titled ´Blockchain technology integration with dealer inventory management´ is written in collaboration with Volvo Group Trucks Operations, a subdivision of Volvo Group - an automotive industry manufacturer. The primary objective of this thesis work is to gain a better understanding of blockchain technology and how it can be used in the Operations management industry, especially supply chain management.

Along with establishing a distributed database which security benefits blockchain technology can provide us with a multitude of benefits in various business processes [26], Some of them are as follows.-

1. As there is no involvement of a trusted third party on a blockchain network, this results into reduction in the transaction cost/time.

2. As a blockchain network provides a distributed database for all network participants, all the transactions are timestamped and visible across the network. This results in increased transparency.

3. As all the network participants are connected on the blockchain network, this enables the interconnection and integration of various IT systems which further leads to the bi-directional flow of digital assets. This improved connectivity helps build trust between the network (supply chain) participants [26], which includes a shared visibility of transactions and information flows across the supply chain.

2.2 Blockchain architecture

Blockchain architecture mainly consists of five modules namely, data source module, transactions, block creation module, consensus module, connection and interface module.

2.2.1. Data source module.

This module helps with the creation of a distributed database (ledgers), which unlike conventional databases do not operate by a certain central authority. The new additions to the network are verified by all the participants in the peer-2-peer network with the help of a consensus protocol. This makes data tampering very difficult, thereby ensuring the network participants a transparent flow of transactions. Data can be written and read via the data source module.

2.2.2. Transaction module

Transactions in the blockchain applications can be defined as the flow of value/asset via the internet/ network. This flow can either take place from the seller to the buyer in the form of asset transfer or the flow of transactions can take place from the buyer to the seller in the form of value transfer. The flow of transactions across the value chain (supply chain) changes the state of data in the past transaction history. The function of broadcasting the transaction agreement between a buyer and seller to the Peer-2-Peer blockchain and addition of new transaction values fall in this module.

2.2.3 Block creation module

The primary function of the block creation module is to permanently record transaction data in a file called block. A blockchain is formed when a certain block is linked to preexisting blocks in a linear flow of transactions. A new block cannot be added to the blockchain network without mining, which is a computational process of solving a mathematical puzzle of a certain complexity. This is done in order to add transaction records to the public distributed ledger. Public blockchain networks such as Bitcoin have a mining process that is energy intensive. The primary reason is the involvement of high powered computers which compute complex mathematical equations in order to verify a set of transactions in a block at the cost of energy consumption.

This principle is called ′Proof of work′. This is not the case for private and permissioned blockchain networks especially for industrial applications. Here the ′Proof of stake′ consensus principle is applied. Here the task of mining is primarily carried out by network participants with majority stake, [27]. In the proposed blockchain technology integration solution in this thesis, Volvo Group will be the majority stake holder, thus will be responsible for the function of validating a set of transactions and adding new blocks on the network. The consensus algorithms e.g. Practical Byzantine Fault Tolerance (PBFT) for such applications are energy efficient and require less computational power as compared to Proof of work (PoW), [28], [29].

2.2.4 Consensus module

The function of confirming and validating a transaction using a consensus algorithm such as the proof of work, proof of stakes, or Byzantine fault tolerance can be defined as the main function of the consensus module. This module ensures the transparency of the transaction data and block-order on the blockchain network.

2.2.5 Connection and interface module

The integration of various web interfaces among network participants as well as synchronizing all the IT systems/platforms in real time are the major function of this module. The end user of the blockchain network primarily interacts with this module. Thus the real time information flow with regards to the contractual status and transaction is crucial. The number of blockchain network participants is directly proportional to the market value generated by an industrial blockchain application. The ability to interact with different companies or industries in order to establish a bi-directional flow of digital assets with each other seamlessly is one of the new research areas included in this module.

2.3 Blockchain technology integration at Volvo Group Trucks Operations (GTO)

In addition to the security benefit, Blockchain technology can bring a multitude of managerial benefits to everyday business practices [26], including: Reduced transaction costs/time resulting from better-preserved blockchain platforms that do not necessitate third-party involvement; Visibility improvement across the supply chain, a result of increased transparency gained via open ledgers that any person can see; and Improved connectivity among trading partners through the integration of digital and physical worlds [26], which includes a shared visibility of transactions and information flows across the supply chain.

Chapter 3.
Proposed Blockchain technology integrated solution

3.1 Blockchain integrated solution

As explained in the previous chapter titled `Background`, the first task for my thesis work was to go through the Volvo GTO DIM operations process. Here the virtual interaction via the IT systems for various supply chain participants such as suppliers, central warehouse facility, regional warehouse facility, dealers was understood. Once the forward logistics flow was understood, the next step was exploring the reverse logistic operations, especially the ´buy-back process´. The buy-back process can be defined as a service provided by Volvo GTO to all its dealers in Sweden, where it purchases all the excess Volvo spare part´s volume from the dealer facility in a periodic manner. The buy-back process enables the restocking of dealer facility with new and updated spare parts. Further information with regards to product recovery management especially with regards to deciding upon the optimal buy-back period for a product can be found in Mondal, S. and Mukherjee, K [19].
In this chapter, a blockchain technology integrated solution which is compatible with the current buy-back process at the DIM team is presented. One of the limitation for this master thesis work was the time constrains of 5 months - January 2019-June 2019 respectively.

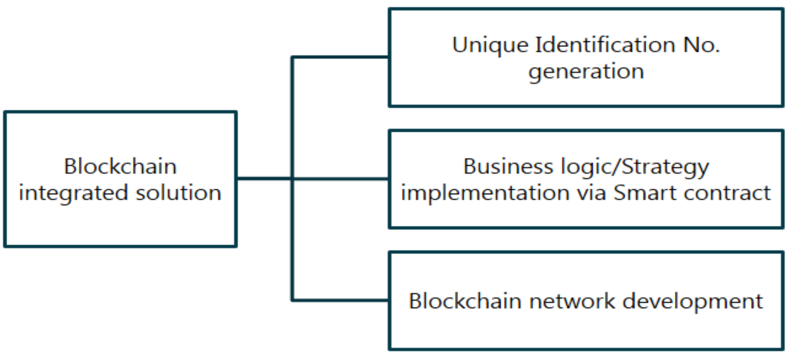

Figure 1. Blockchain integrated solution design flow chart – 1

The design and development of a ´Proof-of-concept´ for blockchain integration at DIM team, Volvo GTO was agreed upon as the master thesis output.

Let us get started with the technicalities of proposed solution for the optimization of the buyback process. As seen from the Figure 1, the proposed Blockchain technology integrated solution consists of broadly three following sections: -

1. Unique identification number generation,
2. Business logic/strategy implementation via smart contracts,
3. Blockchain network development.

Let us further explore each individual section, starting with ´Unique Identification Number´.

3.2 The significance of ´Unique identification number

During my first step of data mining and getting acquainted with the present ´buy-back process´ at DIM Volvo GTO, I noticed the absence of unique identification number let's call it ´Digital ID´ at part level. By this I mean, all the parts of similar type have identical part numbers.
For example: if we consider ´oil filters for Volvo trucks´, all of them will have exactly same part number, irrespective of the date of manufacturing or the date of expiry. The presence of Digital ID is a critical parameter for my master thesis work, as the primary objective was optimizing the buyback process by increasing the traceability at individual part level on the Volvo GTO supply chain network.

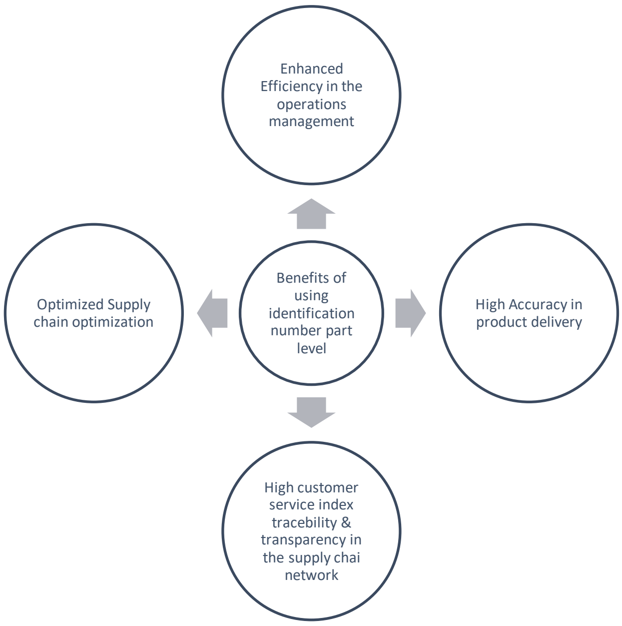

Figure 2. Benefits of using unique identification number part level.

From the Figure 2, I have explained the various benefits of using a digital ID. Thus, working towards the generation of unique identification numbers / Digital ID at individual part level was the first sub-section which needed to be further explored. [3]

3.3 The brain of Blockchain

As explained in Chapter 2, Blockchain technology primarily provides us with a common platform for data storage with high transparency and security functions. What makes blockchain network applications of interest is the level of automation that can be achieved especially for complex industrial processes which involve value and asset transactions known as ´smart contracts´ [5]. Smart contracts can be described in simple words as the additional layer of computational logic added on the blockchain network for inclusion of end-to-end automation. Smart contracts are simple `if-else logic statements` which when compiled together result in automation of transactions occurring at various network nodes in the supply chain process. As observed from the below Figure 3, the second sub-section was ´ Business logic/strategy implementation´.

As the primary objective of this master thesis was integration of a blockchain technology based solution in the reverse logistics process termed as the buy-back process, understanding the terms and conditions of the respective logistics process was critical for the design of smart contracts. These smart contracts can be better understood as a integration of various if-else logic statements [10].
The next step was the detailed literature study of different types of blockchain networks available in the market today in order to narrow-down on the best fit for Volvo GTO (Industry application), [6].

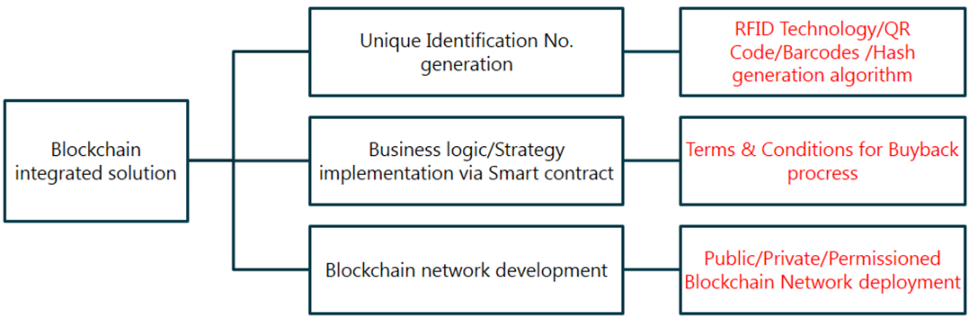

Figure 3. Blockchain integrated solution design flow chart – 2. [9], [2], [3]

3.4 Digital Identity at part level / Unique Identification Numbers Generation

A Digital ID in GTO - Service Market Logistics environment basically means an electronic ID for spare parts which can support the storage of information about the parts i.e. part details, supplier details etc., tracking and tracing of part location, inventory management, avoidance of parts being missed or lost during transit, etc. Presently, at Volvo GTO, RFID (Radio frequency Identification) is being explored actively. During the period of my master thesis work, the ´ innovation and technology ´ team was running a pilot project at the central warehouse facility located in Ghent, France. As the pilot was still in the initial set-up phase, there was absence of data generation. Thus, other alternatives for the purpose of ´Digital ID´ data generation at part level were explored [9]. The other alternative technologies were QR Code, Barcodes and Hash generation algorithm.

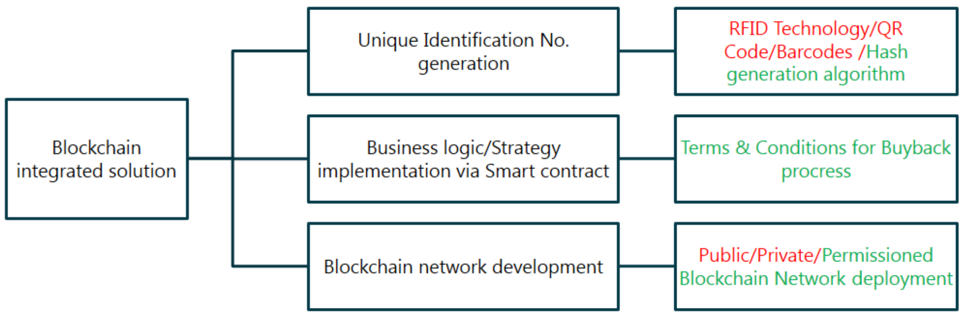

Figure 4. Blockchain integrated solution design flow chart – 3. [9], [2], [3]

The final technologies as well as the respective parameters selected for the design of the ´Proof-of-concept´ can be seen from the above Figure 4. Designing an in-house algorithm which would extract predefined data-sets from various IT systems interacting in the logistics process at Volvo GTO provided an economically viable and functionally sound solution as compared to other alternatives, which were cost intensive.

Thus for the first section, the design of a Hash generation algorithm in order to generate unique identification number at individual part level was decided. For the second section the understanding of the Volvo official terms and conditions was chosen in order to integrate business logic/strategy via the smart contracts on the blockchain network. As this master thesis work is carried out in collaboration with Volvo Group, an industrial blockchain network was needed in order to design a proof-of-concept. Thus, private and permissioned blockchain network was chosen for the third section as seen from the Figure 4.

Chapter-4
Hash Generation Algorithm

4.1 Introduction

During the primary phase of the master thesis work, in order to design a connecting link between various IT systems, certain data sets were extracted from the central warehousing system, Regional warehouse system, Dealer Inventory Management SAP – Enterprise Resource Planning (ERP) system. The main finding of the data analysis was the absence of unique identification number / Digital ID at individual part level in the Volvo GTO supply chain network with the help of example shared in section 3.2 concerning oil filters and absence of unique identification number. The primary necessity for optimizing the buy-back process was extended visibility and traceability at individual Volvo spare part level on the supply chain network.

Thus the presence of unique identification numbers / Digital ID data was extremely crucial in order for the blockchain network to provide Volvo GTO a platform for enhanced traceability and transparency. The various challenges as well as opportunities involved with the blockchain technology integration in the supply chain sector can be better understood with Wang, Y., Han, J.H. and Beynon-Davies, P., 2019 [20]. Thereby the unique identification number data sets for all individual parts is a prerequisite for integrating a blockchain technology based solution. Various digital identification technologies such as RFID technology, Barcode technology and QR code technology were explored in order to find a right fit for this master thesis work. Finally the decision of developing an in-house algorithm was taken as it would provide us with an economically viable and functionally sound solution. The algorithm was named ´Hash generation algorithm´. The use of hash values as a data input to a blockchain based solution is as reliable as the data input from digital identification technologies such as RFID technology, Barcode technology and QR code technology. This can be seen from the research done by Mthethwa, S., Dlamini, N. and Barbour, G., 2018 [21].

4.2 HASH algorithm Proof of Concept design

The first step in the design of the ´Hash generation algorithm´ was to conduct data analysis on various data sets extracted from Demand management system, Central warehousing system, Warehouse demand management and planning system, Volvo dealer facility system. This step was followed by the design of logic flow in the form of data sets through the above mentioned IT systems. Thereby establish a recurring data flow pattern from the spare part supplier to the dealer, which would help me design a logic flow that would interact with the various Volvo GTO systems. The concept was to have a forwards moving logistic flow which in our case could be used for traceability at individual part level. The data flow for the forward moving supply chain was one of the key components for traceability using the hash function from cryptography, [11].

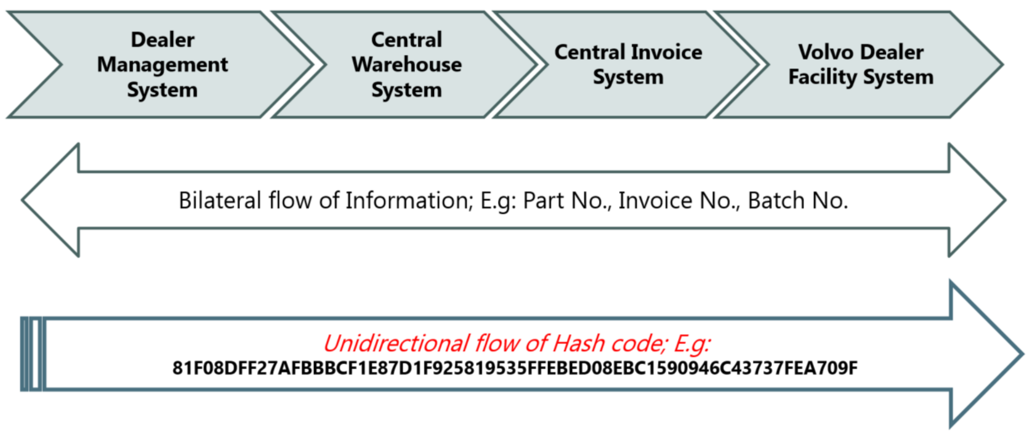

Figure.5: Hash generation algorithm – design concept -1.

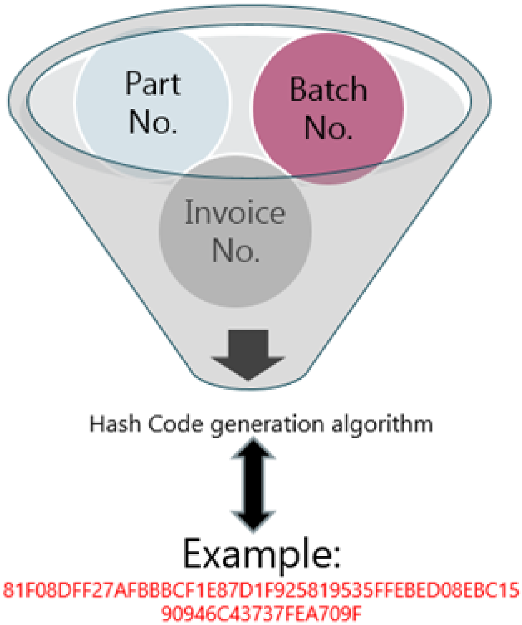

Figure.6: Hash generation algorithm – design concept -2. [11]

The logic was to extract particular data sets from individual Volvo GTO IT systems and the club them together. This can be explained with the help of Figure 6. The respective data set would be selected in such a way to build forward logistics flow. Once all the data sets have been extracted from the above mentioned IT system, they would be clubbed together and hashed. Thereby, using a hashing algorithm principle in order to generate unique Identification numbers for individual Volvo spare parts. This would then be further used as input data for the blockchain technology based solution.

4.3 Hash Generation Algorithm – unique ID generation

As seen from Figure 7 gives a better understanding of the various IT systems involved in the forward logistics process at Volvo GTO. For this thesis work there are primarily four IT systems from which respective data sets have been extracted. The below schematic diagram namely Figure. 8,9,10 and 11 help us understand the various individual data sets extracted from the IT systems.

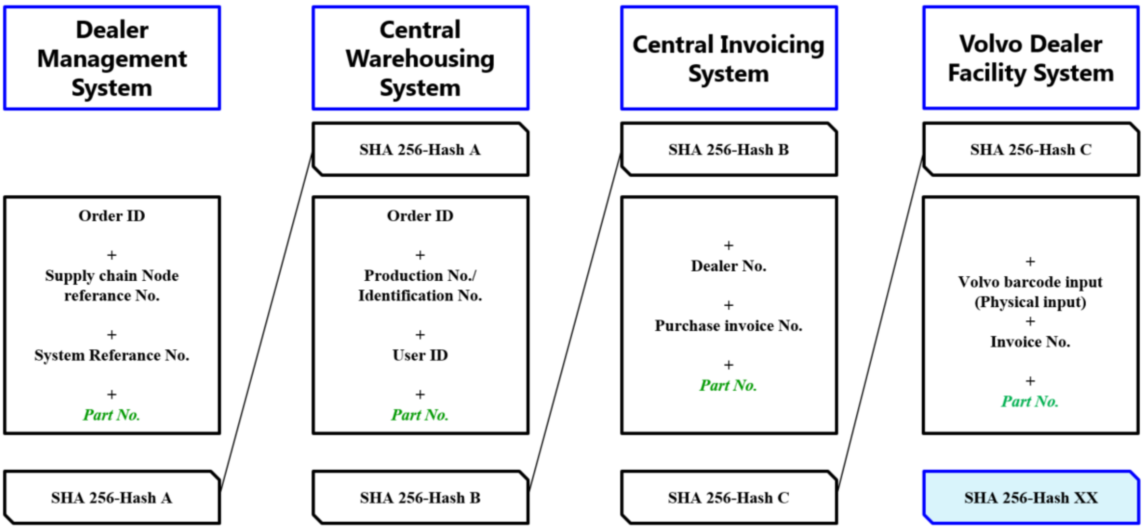

Figure 7. Proof-of-concept - hash generation algorithm for DIM

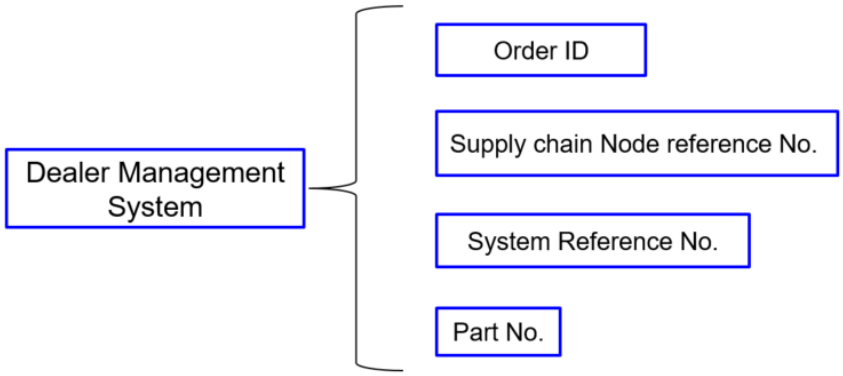

Figure.8: Data sets extracted from the dealer inventory management and planning system.

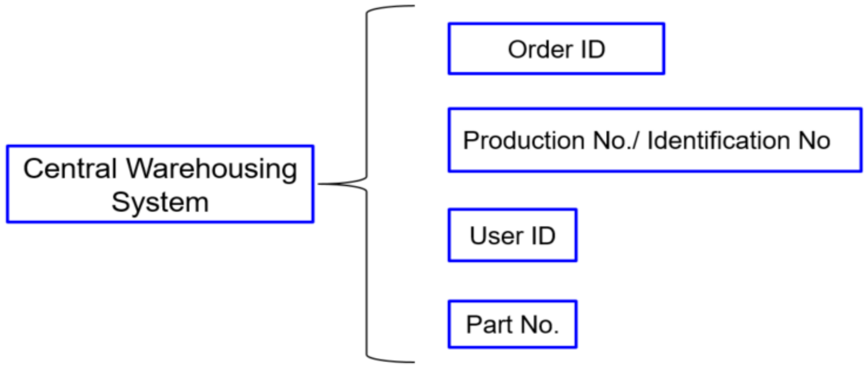

Figure.9: Data sets extracted from the Central warehouse resource planning system.

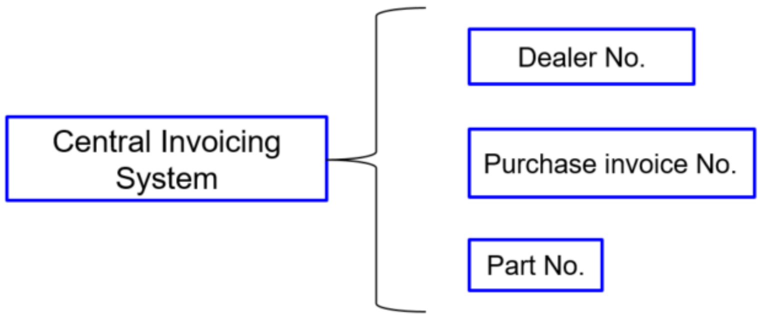

Figure.10: Data sets extracted from the Central invoicing system.

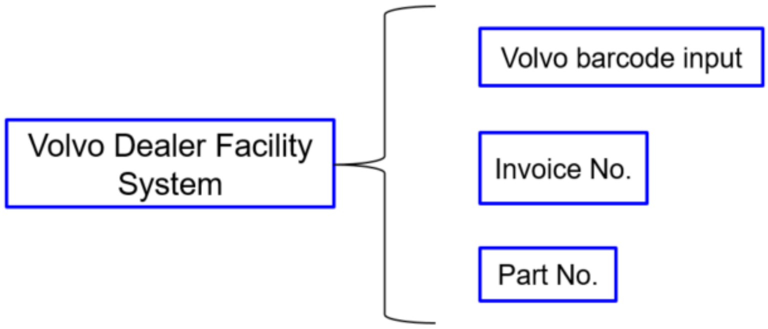

Figure.11: Data sets extracted from the dealer facility resource planning system.

As seen from Figure 11, the input from the barcode found on the packaging of the spare part is one of the data sets used for generation of unique Identification number. Along with serving the above mentioned purpose, input from the barcode also acts as a physical input from individual Volvo spare part. This enables the hash generation algorithm in establishing higher degree of traceability on the Volvo GTO supply chain network for individual spare parts. Here we need to remember that the respective barcode is a pre-existing infrastructure, which can be found on the packaging.

4.5 Segmentation of Automatic and Manual orders

Presently in the DIM team is facing a challenge in the reverse logistics process at Volvo GTO. To better understand the problem statement, let us look at a sample case study. From the Figure 12, we see the flow of Volvo spare part named ´oil-filters´. The flow takes place from the ´order management´ toward ´customer´ via ´warehouse´ and ´dealer´.

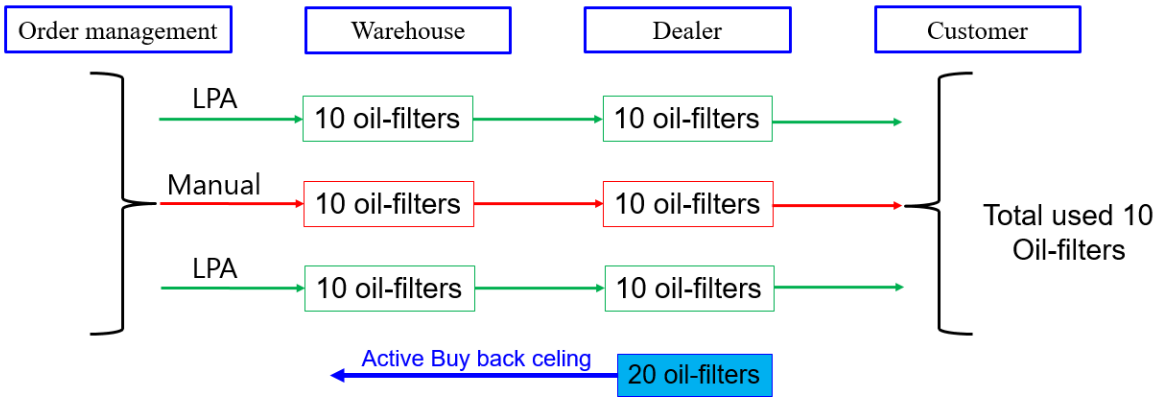

Figure 12. Challenges in the current buy-back process at Volvo GTO.

Once, Volvo Group and the dealer facility enter Logistic Partnership Agreements (LPA), the Dealer inventory management team based upon the forecast calculations refills and restocks the dealer warehouse periodically. Let us call it as the first purchase proposal produced for the transfer of Volvo spare parts. Later if the dealer manually orders few additional Volvo spare parts, which is then followed by an automatic LPA order, that being the third transaction. This results into extension of buy-back coverage on all Volvo spare parts involved in the above defined transactions. Once the spare parts have expired, under the buy-back agreement Volvo as a service provider will buy back all the remaining stock volume from the dealer facility.

Here, Volvo GTO is facing challenges as we are not able to trace individual spare parts which have been automatically pushed to the dealer facility using the LPA agreement and the spare parts manually ordered by the dealer. Here as seen from section 4.3, the hash generation algorithm will generate unique identification number at individual part level. After going through the presence and absence of certain data sets in automatic and manual orders we have designed a proof of concept as seen in figure 15, which will enable Volvo GTO to distinguish between spare parts through the LPA agreement and manually ordered by the dealer.

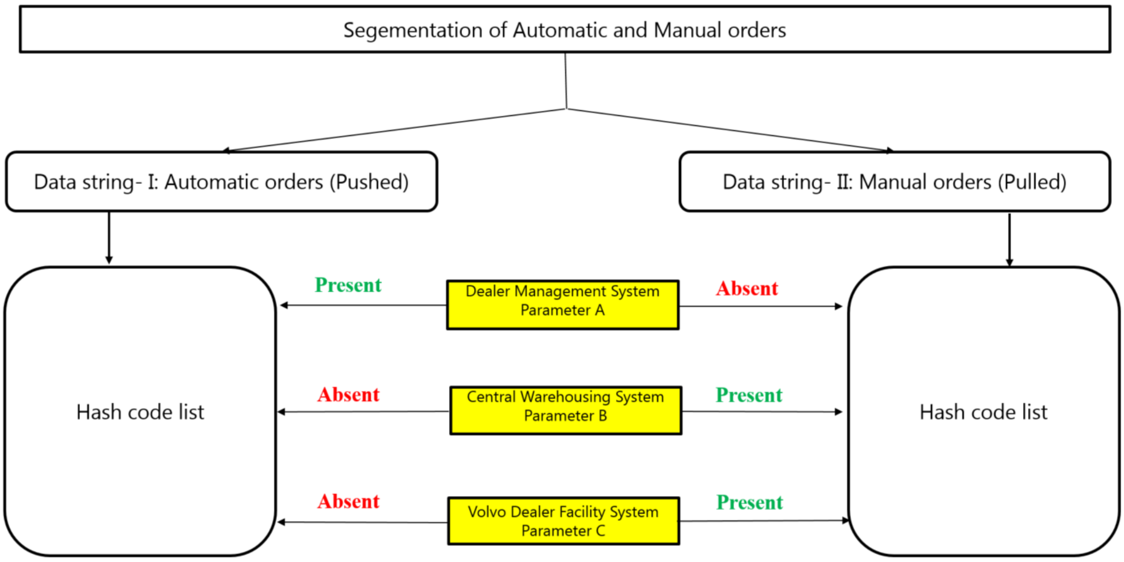

Figure 13. Segmentation of automatic and manual orders.

One of the primary objectives of this master thesis work was to design a logic flow in order to distinguish between (Logistic Partnership Agreements) LPA orders and non-LPA orders for optimized buy-back process. As seen from Figure 13, the automatic orders pushed through the LPA system have the presence of the parameter ´supply chain node reference no.´ which is extracted from the Dealer Inventory Management resource planning system. Also the parameter ´User ID´ which is extracted from the Central warehousing management system and the parameter ´Order reference number´ which is extracted from the central invoicing number.

This information as illustrated in figure 15, can be used for the purpose of segmentation of automatic (LPA) orders and manual orders, using the hash generation algorithm. The output of the above explained concept will be the generation of two files, each consisting of a 64 bit alphanumeric series (hash functions) for LPA orders and manual orders. This will aid in the increased traceability of a genuine Volvo spare part on the supply chain network. As stated earlier the above mentioned proof of concept is in its nascent stage. A pilot project in order to field test the concept is thus proposed later in the discussion section.

Chapter - 5
Design of DIM Blockchain network

5.1 Introduction

As seen from the previous Chapter 4, the invoice and order flow between various IT systems in the Dealer Inventory Management (DIM) process at Volvo GTO, has been explained. This chapter explores the proof-of-concept for DIM blockchain network. In order to understand the design and operation of the DIM Blockchain network, we need to understand the present challenge this master thesis is expected to solve.

In the present Dealer Inventory Management (DIM) operations process especially for the ′Buy-back′ there is a lack of traceability at individual Volvo spare part level and the lack of transparency in the end–to-end supply chain network. As explained in section 2.1, blockchain network can be used to design distributed data storage systems whose access can be public, private or permissioned in nature. For my master thesis work, a private and permissioned blockchain network was decided to be deployed; as it was a right fit for an industrial supply chain network.

5.2 Proof-of-Concept: Blockchain technology application to the Buyback process

The primary function of the share ledger is to record all the transactions taking place in the forward logistics process. The transfer of individual Volvo spare parts and transfer of credit is defined as transaction. Figure 14 illustrates the concept of ´Shared ledger´ and ´Smart contracts´ in the DIM Blockchain network explained. Prior to getting into the various transactions, let's have a look at the various segments designed in order to put the proof-of-concept of the DIM blockchain network together, which will be followed by the various transactions taking place for dealer inventory management (DIM) process.

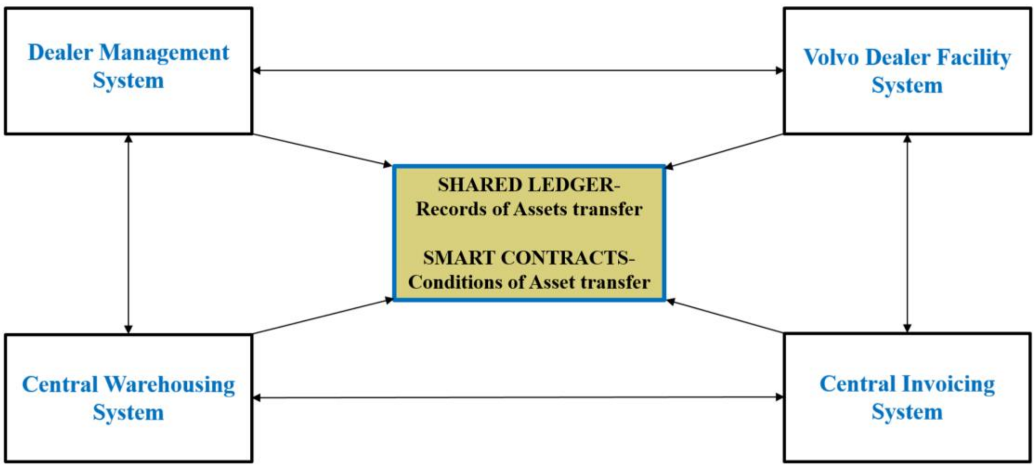

Figure.14: Design of shared ledger and smart contracts for DIM Blockchain network

5.3 The Dealer Inventory Management (DIM) Lifecycle -Blockchain network architecture

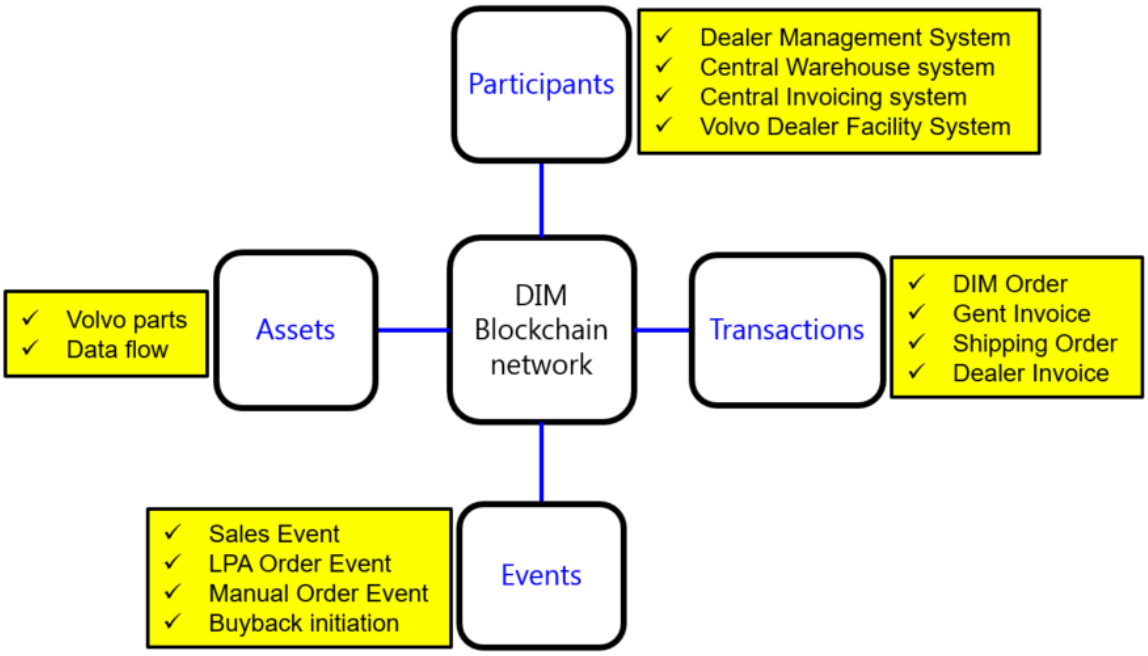

Figure 15. DIM Blockchain network design parameters.

In order to understand the working of the DIM blockchain network, the terms presented in the Figure 15 are important for us.

1. Transactions: A transaction can be defined as the process of document generation triggered due to the flow of Volvo spare parts or credit in the Volvo GTO supply chain network. The various transactions expected to be generated for the DIM Buy-back process are Purchas proposal, Central / regional warehouse invoice, shipping order, dealer invoice etc.

2. Participants: This section can be defined as the various Blockchain network permissioned nodes interacting with each other. For my master thesis work I took the following network participants: - Dealer Management System, Central Warehousing System, Central Invoicing System and Volvo Dealer Facility System.

3. Events: An event can be defined as the trigger for the generation of transactions on the Volvo GTO supply chain network. The events that take place on the DIM Buy-back process are sales event, LPA order event, Manual order event, buy-back initiation.

4. Assets: An asset can be defined as the primary commodity of trade in the supply chain network. For the ′Buy-back′ process at DIM at Volvo GTO, Volvo spare parts and credit-flow are considered to be assets.

5.4 The Dealer Inventory Management (DIM) Lifecycle -Blockchain network

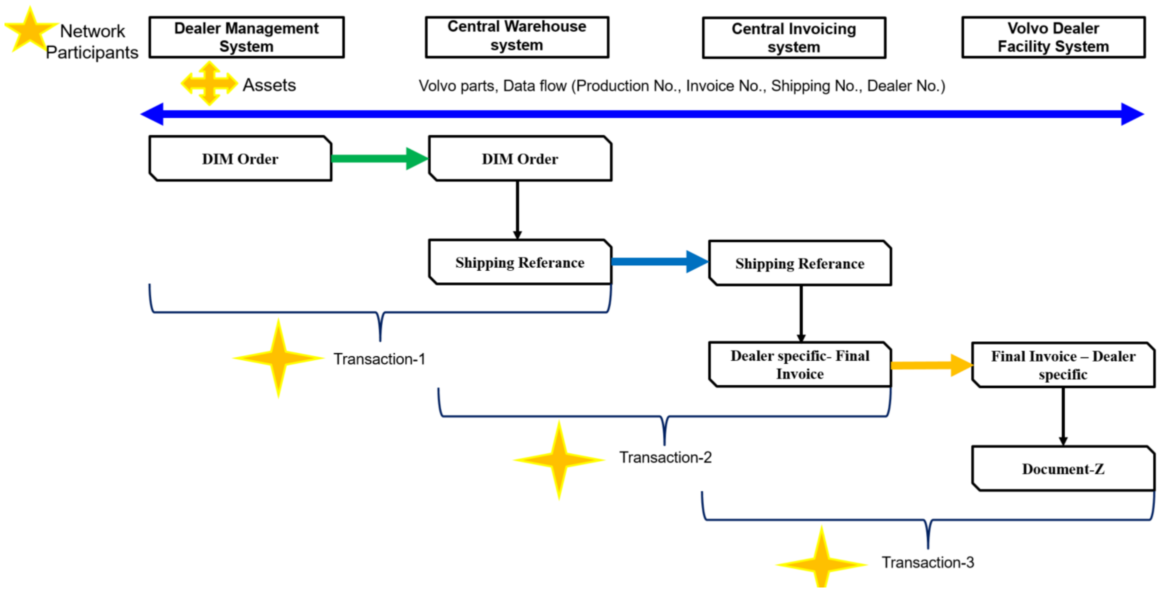

Figure 16. DIM forward logistic case study

Once, we have the understanding of the various building blocks such as participants, transactions, events and assets. Let us further explore a case study where we can better understand the operation process of the DIM blockchain network. As seen from Figure 16, there are four Volvo GTO IT systems namely Dealer Management System, Central Warehousing System, Central Invoicing System and Volvo Dealer Facility System primarily interacting with each other. These IT systems can be defined as network participants. From the figure above we can see the ´transaction-1´ being registered and stored in the shared database on the blockchain network. The generation of ´purchase proposal´ in the Dealer Management System and its interaction with the central warehousing system in order to generate ´shipping invoice´ is termed as transaction-1.

Similarly, when the ´shipping invoice´ from the central warehousing system interacts with Central invoicing system in order to generate ´dealer specific invoice´, transaction-2 is registered in the distributed database. Lastly, when the ´dealer specific invoice´ from the Central invoicing system interacts with the Volvo dealer facility system a final document is generated which includes all the individual spare parts along with the LPA contract terms and conditions. Let us call it ´document Z´ which is registered as transaction-3 in the distributed database on the blockchain network.

5.5 Block-Assumed to have a valid proof of transaction

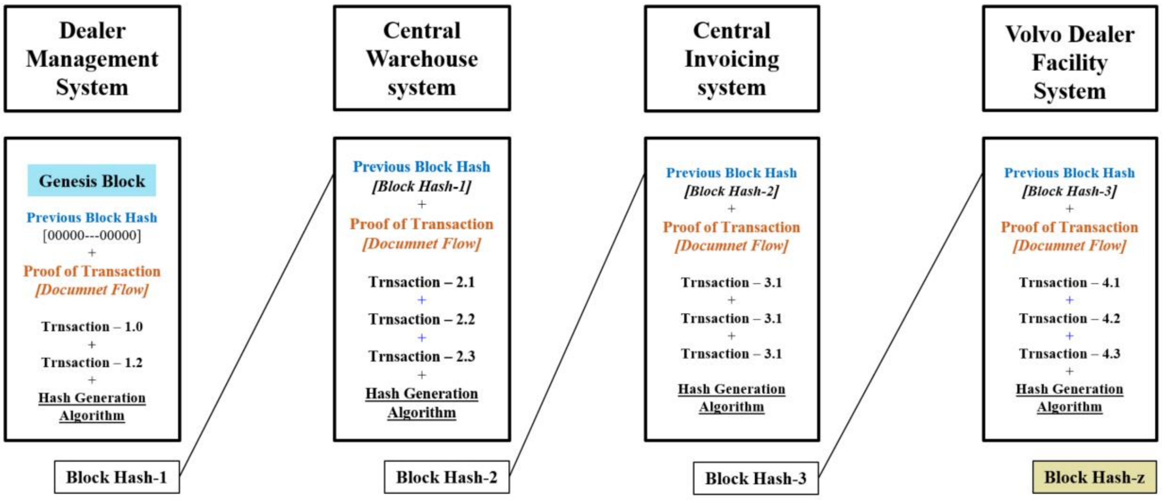

Figure 17. DIM Blockchain network

The Figure 17 looks very similar to the Figure 7 in section 4.3 which explains the flow of data between network participants and the generation of unique identification numbers whereas Figure 17 illustrates similar concept but at a macroscopic scale. The first block of a blockchain network is termed the genesis block, which is generated at Dealer management system. Each individual block stores all the transactions taking place in the form of a hash code-which is unique in nature, there by generating a trail of digital identity across the supply chain network. This further enables enhanced traceability of the assets and transparency of transactions on the supply chain network. From Figure 17, we gain a holistic understanding of how the blockchain would look like and function accordingly for the DIM application at Volvo GTO.

Chapter – 6
Volvo GTO IT system

6.1 Introduction

Presently there are a set of independent IT systems, which work together in the Dealer Inventory Management Process.

The major IT systems are as follows:

1. Dealer Management System
2. Central Warehousing System
3. Central Invoicing System
4. Volvo Dealer Facility System

IT systems are categorized into three sections, namely

1. Dealer facility,
2. Sales organization,
3. Parts organization.

One of the most important challenges for this thesis work was to understand the operation and interaction of the respective IT systems especially for the buyback process at Dealer Inventory Management (DIM) team. From Figure 20 we can better understand the flow of purchase orders, Discrepancy and credit.

Let us have a look at each of these constituting procedures in the DIM process.

6.2 Order and Invoice flow

Figure 18 shows the invoice and order flow at Volvo Group Truck Operations (GTO). At the dealer facility, we have Volvo Dealer Facility System, which enables the dealer to interact with the Volvo GTO office. This communication happens via the Dealer Management System, Central Warehousing System and Central Invoicing System, depending upon the type of order placed by the dealer. The Central warehousing system is an SAP Enterprise Recourse Planning systems primarily designed for resource planning and management.

The Regional warehousing system is designed for the purpose of having a support warehouse. A support warehouse can be defined as a regional warehouse for a county whereas central warehouse is usually designed for a cluster of countries or a continent. As seen from figure 18, for day orders request put-in by the dealer, the regional warehouse is brought into the Dealer Inventory Management (DIM) process and for Stock order requests put-in by the dealer the central warehouse is brought into the Dealer Inventory Management (DIM) process.

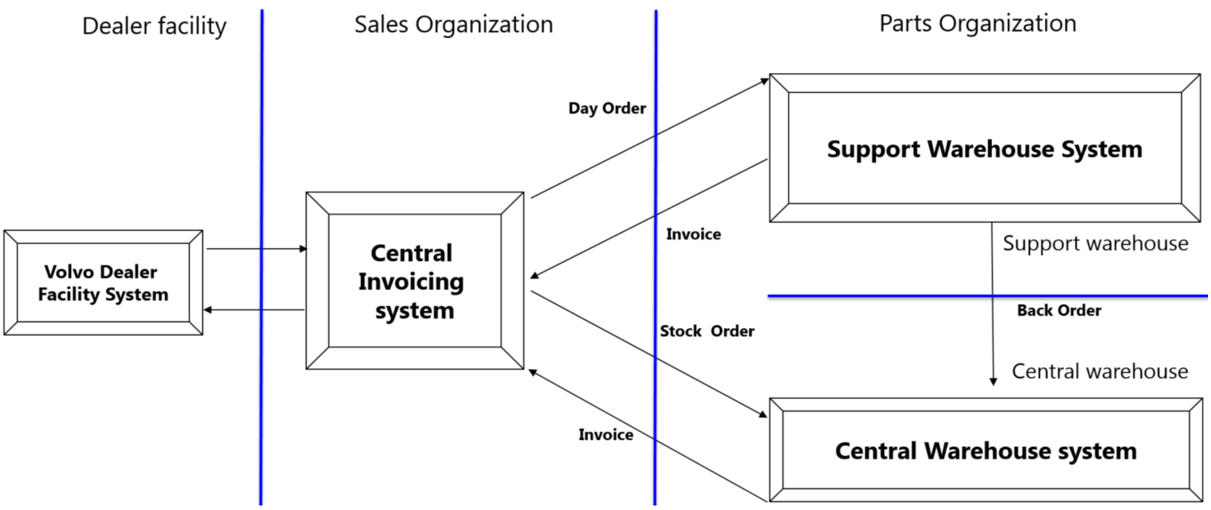

Figure 18. Order and Invoice flow Volvo GTO

6.3 Discrepancy flow

The discrepancy can be defined as the by-product of the Buy-back process. As defined in the earlier chapter, Volvo Group credits the dealers for all the spare-part stock volumes, which either have been expired or are technologically obsolete. Although in the North-European markets, the respective dealer and Volvo GTO have to undergo an agreement titled ´Logistics Partnership Agreement - LPA ´ where Volvo GTO has the responsibility of crediting the dealers for all the excess of spare-part stock volumes and simultaneously replacing it with healthy stock in a periodic manner. From figure 19, we observe the flow of discrepancy from dealer facility to either support warehouse or central warehouse. Once the discrepancy reaches the regional / support warehouse it is shipped to the central warehouse for either being scrapped or refurbished.

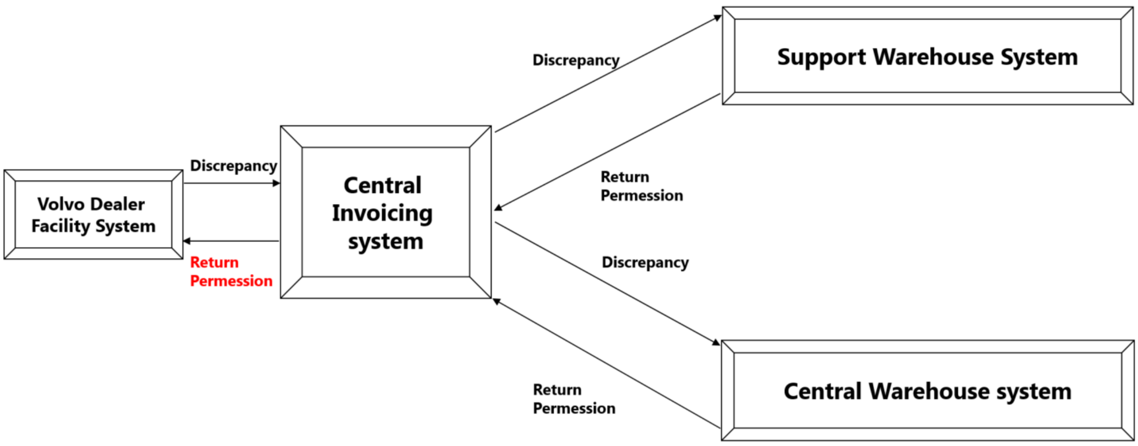

Figure 19. Discrepancy flow Volvo GTO

6.4 Return and Credit Note flow

From Figure 20, we can observe the flow of credit from the central invoicing system i.e. to the Volvo dealer facility system. The Volvo spare parts extracted in the buyback process spare parts flow from the dealer facility to either the regional warehouse or the central warehouse.

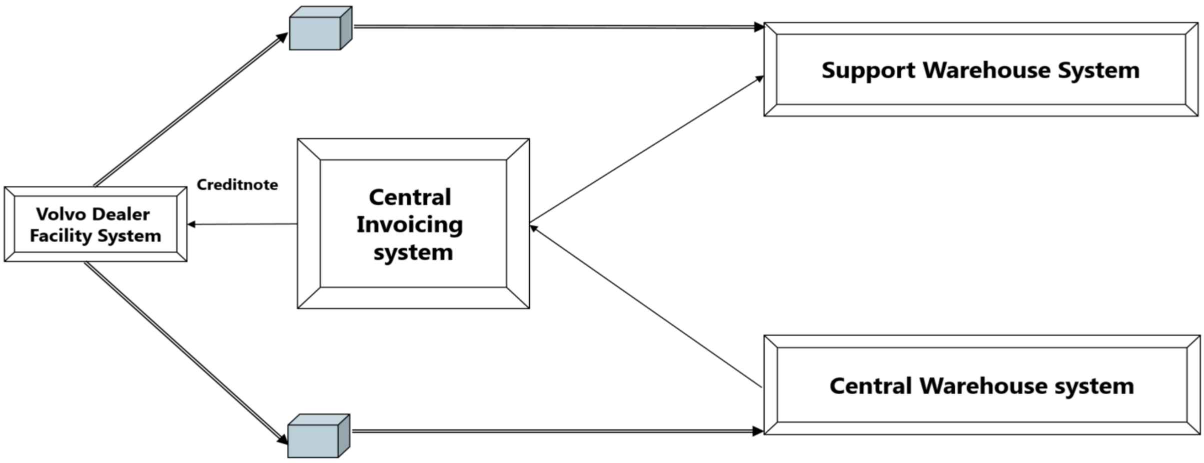

Figure 20. Return and Credit Note flow

Chapter -7
Smart contracts

In [18], the concept of business contracts is defined as a set of promises agreed to in the meeting of minds. Contracts can be considered as the building blocks of trade and commerce in our society.

7.1 What is a smart contract?

Smart contracts is the answer to the question how blockchain technology can add value to the pre-existing field of operations management. Blockchain technology in simple words can be described a distributed database. By the integration of smart contracts, there is an additional layer of automation between all the nodes on the blockchain network, regardless of whether a smart contract represents a product warranty/insurance agreement, part/product buyback agreement or some sort of agreement between the respective network participants on a blockchain network. In order for the right sequencing of blocks on the blockchain network, smart contracts needs to be triggered in a stipulated and structured manner i.e. the terms and condition of the respective contract need to be followed accurately. A smart contract can be defined as a computer program which is self-executing in nature when a set of pre-defined / pre-coded conditions are met. In simple words smart contracts is the business logic coded in simple ´if-else´ conditions and statements. Smart contracts enable the various terms and conditions of a business process to be coded in the format of simple ´if-else´ statements. This aids in the self-execution of various business transactions as and when the preceded conditions are met. This increases the level of automation on the blockchain network.

Smart contracts enable the enforcement of an agreement between the various parties involved in the business process, since the various terms and conditions of a business process are coded in the form of computer logic, i.e. we can say that smart contracts enable the enforcement of an agreement between the various parties involved in the business transaction process. Here smart contracts can be further developed to inculcate various subsections of a business transaction such as the rules, rewards and penalties similar to a convention contract written on a piece of paper. This opens up further challenges and opportunities for the degree of automation on the blockchain network.

As we know blockchain technology can be defined as a distributed ledger technology which generates distributed storage on the respective network. Here the integration of smart contracts adds-in a layer of automation which results into the final completion of a business process, generally in the form of transfer of value – in the form of credit or an asset. As per my observation, the heavy vehicle industry faces a challenge in the supply chain. Generally, the physical supply chains are well integrated although the supporting IT systems where the flow of data takes place are often disintegrated. As we know, blockchain technology provides us with distributed database solution, which is immutable in nature; time stamped and operates in real time. In order to integrate blockchain technology with the preexisting IT systems we must explore the various IT systems that interact with each other for the reverse logistic process.

7.2 Smart contracts for the DIM Blockchain network

Prior to the development of blockchain technology for operations management application, generally there is a time lag/delay between the design and development of a contractual agreement and execution of the respective agreement. For large scale supply chain networks comprising of multiple network participants spread across the globe, there is a variation in the execution of a contract as compared to the terms and conditions of the agreement. This shows that generally even though the supplier and the purchasing party agree to a certain terms and conditions of a contract, it does not guarantee that the respective nodes (manufacturer/supplier/dealer/customer) in the supply chain network will be able to deliver accordingly. [7]

When exploring the integration of smart contracts into the blockchain network, it is important for us to understand exactly what section of the supply chain network we are focusing on as well as the automation of Key parameters of interest to us as an organization, which will add value to the dealer inventory management process.

```
Assumption: Asset: Volvo Oil Filter
If
{ ---------Transactions 1----------} ______________Event-1
          Else_if
                 { ---------Transactions 2----------} ______________Event-2
                    Else_if
                           { ---------Transactions 3----------} ______________Event-3
                             Else_if
                                    { ---------Transactions 4----------} ______________Event-4
Then
{------------Outcome 1 or 2 or 3 or 4 ------------}
```

Figure 21. Smart contract logic design. [10]

This thesis explored the reverse logistics process i.e. the buy-back process. The key parameters in the domain of reverse logistics were the*´ traceability of the genuine Volvo parts ´, ´Credit flow between the dealer and Volvo Group´, ´transparency of the system´ and ´return of investment´.* From the above-mentioned parameters, the most important is the Volvo parts flow (forward logistics flow) from Volvo Group suppliers all the way to the dealer and the credit flow from the dealer to Volvo Group. The reason why understanding the ´ forward logistic processes ´ is important because it aids in building a business logic for enhanced traceability with the help of cryptographic principles called ´Secure Hashing Algorithm´ and blockchain technology. Similarly, the reason for understanding the ´ credit flow ´ is important as it aids in building a business logic in the form of smart contracts, which further results in increasing the level of automation in the buyback process. [8]

In the above figure, I have explained the working of a smart contract in the context of a DIM blockchain network. Here I have used the terms namely ´event´ and ´transaction´ which have been defined in section 5.3. As seen from the figure 21, an event triggers a set of transactions which further initiates the execution of smart contract. If a certain set of transactions are initiated such as generation of ´Logistic Partnership Agreement (LPA) - contract´ from the dealer to Volvo GTO. This would further trigger a predefined outcome of complete buyback from Volvo GTO as a service provider to the dealer. The generation of ´Buy-back´ contract would further trigger a set of event and henceforth a set of transactions would be generated at each step. [11]

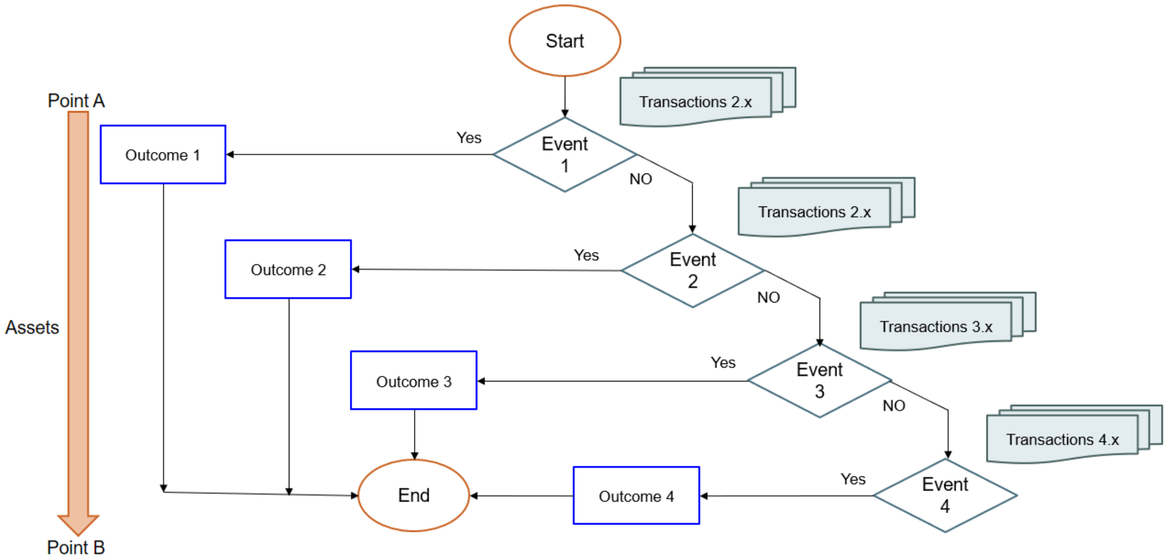

Figure 22. Flow chart – smart contracts.

As explained in the chapter titled ´DIM Blockchain network´, we define ´event´ as the trigger for the generation of transactions on the Volvo GTO supply chain network. The events that take place on the DIM Buy-back process are *sales event, LPA order event, Manual order event, buy-back initiation.* The smart contracts start executing when a set of pre-coded conditions are met. As seen from figure 22, the smart contract is designed to have a step-by-step ´if-else if´ logic structure.

For the occurrence of ′Event-1′ all the transactions with regards to the respective event are taken into consideration and the logic flow is designed to either reach a pre-defined outcome or flow further to ′Event-2′. In a similar way smart contract goes step-by-step through all the predefined conditions of a process using ′if-else if′ logic structure.

As seen from the above flow chart in figure 22, if a certain set of conditions are met the smart contract executes a pre-defined outcome and if the respective conditions are not met, the smart contracts executes a separate set of pre-defined outcome. Although smart contracts seem very similar to the ′if-else′ conditions and statements; they play an important role when it comes to the final business transaction (especially in a supply chain network) which is predominately the transfer of value in the form of credit or asset. Blockchain technology and its unique characteristic to enable the transfer of value over the internet comes into play. Due to the absence of a third party intermediator such as a bank or a financial regulatory agency the process of value transfer over the supply chain network is very economically viable and functionally sound as the transaction of value between multiple blockchain network participants happens in real-time.

Discussion

In the previous chapters, I have defined the problem statement, the present status of the Volvo GTO system, the challenges which we face due to the lack of traceability in the Volvo GTO - supply chain network, the proposed blockchain integration model, design of the proof-of-concept – DIM blockchain network and smart contracts respectively. In this thesis work, I have worked on building a proof-of concept – blockchain integrated solution. As seen in chapter 5: Explanation of the DIM blockchain network solution, the respective proof-of-concept blockchain network can provide increased traceability, especially at individual part level in the supply chain network. As seen from chapter 7: Explanation of smart contracts execution, the integration of smart contracts further increases the transparency between multiple parties connected to the supply chain network. Thereby, in this master thesis work, I have defined various parameters critical for the design and development of the proof-of-concept - Blockchain integrated solution. In the last couple of years we have seen rapid development in the field of Blockchain technology in various domains such as finance, supply chain management, defense grade communication, asset management such as :- identity, product/commodity, insurance.
This has resulted in a need for government regulation especially for the finance and asset management applications. Thereby resulting in the design and development of various international standards such as:

1. ISO/DIS 22739 Blockchain and distributed ledger technologies — Terminology [14],

2. ISO/AWI TS 23259 — legally binding smart contracts [15],

3. ISO/CD TR 23455 — Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems [16].

Another noteworthy development in this domain has been the establishment of ´ Blockchain in Transport Alliance ´ also known as ´BiTA´, [13].

The primary objective of ´ BiTA ´ is defined as providing a common platform to all its members (which are from the freight, transportation, logistics and affiliated industries) in order to standardize the adoption of latest technologies in order to increase higher operating efficiency as well as achieve sustainable transportation goals. [13]

As seen from the concepts presented in chapter 4: Hash generation algorithm and chapter 7: smart contracts we arrive at the following conclusions:

The integration of private / permissioned industrial blockchain network with a the Volvo Group supply chain network, which is a multi-layer / multiparty supply chain network, can enable increased Volvo spare part traceability as well as transaction flow transparency across the value chain. This capability for a service provider such as Volvo GTO results into a multitude of opportunities such as efficient recourse planning and operations management.

Recommendations / Future steps

The functionality to have enhanced traceability of assets and transparency in the transaction flow across a supply chain is very desirable. The reason being, it provides with the end-to-end recourse planning and efficient operations management. Especially for Volvo GTO as a service provider which has operations / supply chain networks in 190 countries and manufacturing units in 30 countries i.e. multi-layer / multiparty supply chain network. This master thesis presents the design and development of a proof-of-concept which explores the integration of blockchain technology solution in the buy-back process respectively. The next step will be to work on the design and development of a proof-of-work concept where a pilot project involving possibly a fast segment Volvo spare part such as an oil-filter is recommended. Once complete traceability of individual Volvo spare part (example: Oil filter) across the supply chain network achieved the next recommended step will be to scale-up the scope of the respective pilot project, by increasing the number of Volvo spare parts to be traced on the blockchain network.

Conclusion

This master thesis presents a proof of concept where blockchain technology is integrated with pre-existing infrastructure in Gothenburg, Sweden. The proof of concept was successful in enabling Volvo GTO to distinguish between automatic orders and manual orders thereby increase the traceability at part level across the supply chain.

During the course of this thesis work, it was observed that Volvo GTO is new to the field of integrating blockchain technology and there is a lack of skilled workforce as well as IT infrastructure. Although the executive management is skeptical towards integrating an open source software solution such as blockchain technology they are willing to further explore this proof of concept in the form of a pilot project here in Sweden. The scale of transactions along with the number of supply chain participants involved in the forward logistics process at Volvo GTO makes the integration of blockchain technology challenging and at the same time enable Volvo group in creating value in the form of cost reduction, process automation and supply chain optimization. The value generated by the proposed solution in terms of estimated cost saving is highest in North America followed by Asia and then Europe. In Sweden there are approximately 300 Volvo group dealer facilities with an annual reverse logistic cost of about 100 Million SEK of which 40 % comes from the buyback process.

I look forward to the results of the planned pilot project as it can validate the proposed proof of concept in this master thesis as well as provide data with regards to the practical implementation / integration of blockchain technology in the field of operations management.

References

1. Golosova, J. and Romanovs, A., 2018, November. The Advantages and Disadvantages of the Blockchain Technology. In *2018 IEEE 6th Workshop on Advances in Information, Electronic and Electrical Engineering (AIEEE)* (pp. 1-6). IEEE.
2. Abeyratne, S.A. and Monfared, R.P., 2016. Blockchain ready manufacturing supply chain using distributed ledger.
3. Banerjee, A., 2018. Blockchain technology: supply chain insights from ERP. In *Advances in Computers* (Vol. 111, pp. 69-98). Elsevier.
4. Kamath, R., 2018. Food traceability on blockchain: Walmart's pork and mango pilots with IBM. *The Journal of the British Blockchain Association*, *1*(1), p.3712.
5. Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H., 2017, June. An overview of blockchain technology: Architecture, consensus, and future trends. In *2017 IEEE International Congress on Big Data (BigData Congress)* (pp. 557-564). IEEE.
6. Badzar, A., 2016. Blockchain for securing sustainable transport contracts and supply chain transparency-an explorative study of blockchain technology in logistics.
7. Sermpinis, T. and Sermpinis, C., 2018. Traceability decentralization in supply chain management using blockchain technologies. *arXiv preprint arXiv:1810.09203*.
8. Jeppsson, A. and Olsson, O., 2017. Blockchains as a solution for traceability and transparency.
9. Kubáč, L., 2018. RFID Technology and Blockchain in Supply Chain.
10. Liu, K., Desai, H., Kagal, L. and Kantarcioglu, M., 2018. Enforceable Data Sharing Agreements Using Smart Contracts. *arXiv preprint arXiv:1804.10645*.

11. Mthethwa, S., Dlamini, N. and Barbour, G., 2018, December. Proposing a blockchain-based solution to verify the integrity of hardcopy documents. In *2018 International Conference on Intelligent and Innovative Computing Applications (ICONIC)* (pp. 1-5). IEEE.

12. Blockchain for smart communities_ Applications challenges and opportunities.

13. https://www.bita.studio/

14. https://www.iso.org/standard/73771.html

15. https://www.iso.org/standard/75095.html

16. https://www.iso.org/standard/75624.html

17. https://volvogroup.sharepoint.com/sites/nc-group-trucks-operations-news/SitePages/blockchain-for-more-secure-supply-chains.aspx

18. Szabo, N., 1997. Formalizing and securing relationships on public networks. *First Monday*, *2*(9).

19. Mondal, S. and Mukherjee, K., 2006. Buy-back policy decision in managing reverse logistics. *International Journal of Logistics Systems and Management*, *2*(3), pp.255-264.

20. Wang, Y., Han, J.H. and Beynon-Davies, P., 2019. Understanding blockchain technology for future supply chains: A systematic literature review and research agenda. *Supply Chain Management: An International Journal*, *24*(1), pp.62-84.

21. Mthethwa, S., Dlamini, N. and Barbour, G., 2018, December. Proposing a blockchain-based solution to verify the integrity of hardcopy documents. In *2018 International Conference on Intelligent and Innovative Computing Applications (ICONIC)* (pp. 1-5). IEEE.

22. Chaum, D., 1983. Blind signatures for untraceable payments. In *Advances in cryptology* (pp. 199-203). Springer, Boston, MA.

23. Meng, W., Wang, J., Wang, X., Liu, J., Yu, Z., Li, J., Zhao, Y. and Chow, S.S., 2018, August. Position paper on blockchain technology: smart contract and applications. In *International Conference on Network and System Security* (pp. 474-483). Springer, Cham.

24. Chow, S.S., 2007, December. Running on karma–P2P reputation and currency systems. In *International Conference on Cryptology and Network Security* (pp. 146-158). Springer, Berlin, Heidelberg.

25. Nakamoto, S., 2008. Bitcoin: A peer-to-peer electronic cash system.

26. Min, H., 2019. Blockchain technology for enhancing supply chain resilience. *Business Horizons*, *62*(1), pp.35-45.

27. Kang, J., Xiong, Z., Niyato, D., Wang, P., Ye, D. and Kim, D.I., 2018. Incentivizing consensus propagation in proof-of-stake based consortium blockchain networks. *IEEE Wireless Communications Letters*, *8*(1), pp.157-160.

28. Castro, M. and Liskov, B., 1999, February. Practical Byzantine fault tolerance. In *OSDI* (Vol. 99, No. 1999, pp. 173-186).

29. Mingxiao, D., Xiaofeng, M., Zhe, Z., Xiangwei, W. and Qijun, C., 2017, October. A review on consensus algorithm of blockchain. In *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (pp. 2567-2572). IEEE.

30. https://coinmarketcap.com/