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Subject: **Logistics 4.0: technologies and applications in TEL**

Logistics 4.0 and Supply Chain Management 4.0 or smart supply chain management concern the various aspects of end-to-end logistics and supply chain management in the context of Industry 4.0, the Internet of Things, cyber-physical systems, emerging technologies, advanced data analytics and (semi-)autonomous decisions enabled by AI.

This assignment is to survey the technologies, methodologies and their applications w.r.t. the concept of logistics 4.0, in a defined domain within TEL (i.e., Harbor, container terminal etc.)

The main tasks of this literature survey include the investigations of

- Concept of Logistics 4.0
- Available technologies & methodologies
- Demonstration based on case studies
- Challenges and implications of Logistics 4.0
- Proposition of future work

This report should be arranged in such a way that all data is structurally presented in graphs, tables, and lists with belonging descriptions and explanations in text.

The report should comply with the guidelines of the section. Details can be found on the website.

The supervisor,

Delft University of Technology
Department of Transport Engineering and Logistics

Logistics 4.0: Technologies and Applications in TEL

Literature Assignment

Alex Steenkamp

Supervisors:
Dr. Ir. X. Jiang

Delft, December 2018

Preface

This literature review is part of the curriculum of the Master of Science Mechanical engineering, track Transportation Engineering and Logistics (TEL) of the Delft University of Technology. It has been a very educational and insightful process to learn more about port hubs and communities and how they operate and the concept and possible applications of logistics 4.0.

I would like to thank my supervisor dr. ir. X. Jiang for providing an assignment topic as interesting as this one, for reading all my work and providing feedback and guidance.

Summary

Maritime transport is the backbone of international trade. According to the International Maritime organization (2013) [1] international shipping transports around 90% of the global trade. Port communities are an indispensable part of global transportation. In an ever more globalizing world it is expected that international trade will keep rising, resulting in a higher throughput of cargo in ports. Ports will have to be able handle this higher throughput, preferably by increasing operational efficiency. In the meantime shippers are also demanding better supply chain transparency. In the past years new technologies were introduced that have the potential to revolutionize the logistics and supply chain industry. This has led to the creation of the concept of logistics 4.0, which could prove instrumental in solving the mentioned challenges and has the potential to disrupt the port community.

The main question answered in this report is: *"What possible applications does logistics 4.0 provide in port communities and how is the port community affected by them?"*

In order to answer the main question it is first necessary to understand the port community. The players that make up the port community, their way of operating, their goals and the interrelationships are researched. Based on Henesey (2006) [2], the scope of this report on the port community includes: the port authority, the shipping lines, the terminal operators, the freight forwarders, the shipping agents, third and fourth party logistics providers, customs, towage and pilotage companies, waste reception facilities, ship chandlers and repair services. Not all players have the same objectives. All players in the port community have a drive for efficient operations though. For most players this is because of the high level of competition they face.

Next the concept of logistics 4.0 is defined. Logistics 4.0 is set to improve the efficiency of the flow of goods, through high levels of automation in the transport process. Logistics 4.0 is also set to improve the flow of information. Increased pervasive sensing, combined with ubiquitous connectivity creates unprecedented levels of data, which can be used to track components and goods as they travel through the supply chain. This allows for a much better visibility of the status and position of goods. Ubiquitous connectivity also allows different components to communicate with one another, and increased computing power and data analytics make large sums of data transmitted by all parts of the logistics network more valuable than before. Next the technologies that enable this new and improved form of logistics and supply chain management are presented. They are: Internet of Things, RFID, Big Data, machine learning and blockchain technology.

In order to understand the effect logistics 4.0 will have on the port community, multiple applications are thoroughly investigated. These applications are: moving the global supply chain to the blockchain, the introduction of smart containers, the application of condition-based maintenance strategies for vessels and cranes, the automation of terminal operations and smart customs control. By moving the global supply chain to the blockchain the transparency and ease of communication in the supply chain could be greatly improved. The introduction of smart containers could be great for status and position monitoring of the cargo. The security of the container is also set to increase, since sensors can identify whether or not a container has been opened at an unexpected time. Condition-based maintenance uses Big Data and machine learning to eliminate

unnecessary maintenance by assessing and predicting the health of equipment. The automation of container terminals greatly improves the operational efficiency and allows for faster operations and a higher terminal capacity. Smart customs management uses the improved supply chain visibility and combines this with machine learning models to assess the risk of containers. On the basis of this improved and automated risk-assessment it is decided which containers are to inspected and which are not.

Finally the challenges that are yet to be overcome for the successful implementation of logistics 4.0 applications are researched. The first challenge is the lack of mutual trust between certain organizations, mainly shipping lines. This lack of mutual trust could be a roadblock for the implementation of a single blockchain, to handle the global supply chain, as organizations would prefer to build their own. A second challenge concerns cyber security. When many processes are digitized, they become vulnerable to cyber criminals, hackers or even rival governments. In order to successfully apply logistics 4.0 applications, organizations must establish a high level of cyber security. The final challenge presented is a social one. The introduction of logistics 4.0 is accompanied with automation, and thus an inevitable loss of jobs. This challenges is researched from an ethical and a financial viewpoint.

Dutch Summary

Maritiem vervoer vormt de ruggengraat van de internationale handel. Volgens de International Maritime Organisation (2013) [1] wordt ongeveer 90% van de wereldhandel getransporteert door de scheepvaart. Mede doordat de wereld steeds meer globaliseert, wordt verwacht dat de internationale handel zal blijven stijgen, resulterend in een hogere doorvoer van vracht in havens. Havens zullen deze hogere doorvoer moeten kunnen verwerken, bij voorkeur door de operationele efficintie te verhogen. In de tussentijd eisen verladers ook een betere transparantie van de supply chain. In de afgelopen jaren zijn nieuwe technologien gentroduceerd die de potentie hebben om een revolutie teweeg te brengen in de logistieke sector. De zogeheten logistiek 4.0 zou instrumentaal kunnen zijn in het oplossen van de genoemde uitdagingen en heeft de potentie om de havengemeenschap te revolutionaliseren.

De hoofdvraag die wordt beantwoord in dit rapport is: *"welke mogelijke applicaties heeft logistiek 4.0 in havengemeenschappen en hoe zal de havengemeenschap door deze beïnvloed worden"*

Om de hoofdvraag te beantwoorden, is het eerst noodzakelijk om de havengemeenschap te begrijpen. De leden die deel uitmaken van de havengemeenschap, hun manier van werken, hun doelen en de onderlinge relaties worden onderzocht. Op basis van Henesey (2006) [2] omvat de strekking van de havengemeenschap in dit rapport: de havenautoriteit, de rederijen, de terminals, de expediteurs, de havenagenten, logistieke dienstverleners van derde en vierde partijen, de douane, sleepvaart en piloot bedrijven, afvalontvangstfaciliteiten, scheepsbevoorraders en reparatiediensten. Niet alle leden van de havengemeenschap hebben dezelfde doelen. Echter hebben alle leden van de havengemeenschap wel een drive voor efficinte operaties, voor de meesten vanwege de hoge mate van concurrentie waarmee ze worden geconfronteerd.

Vervolgens wordt het concept van logistiek 4.0 gedefinieerd. Logistiek 4.0 is ingesteld om de efficintie van de goederenstroom te verbeteren, door een hoge mate van automatisering in het transportproces. Logistiek 4.0 is ook ingesteld om de informatiestroom te verbeteren. Het gebruik van een groot aantal sensoren, gecombineerd met alomtegenwoordige connectiviteit, creert een ongekend niveau aan data, wat kan worden gebruikt om componenten en goederen te volgen terwijl ze door de supply chain reizen. Dit zorgt voor een veel betere zichtbaarheid van de status en de positie van de goederen. data-analyse maakt grote hoeveelheden gegevens die door alle delen van het logistieke netwerk worden verzonden, waardevoller dan ooit. Vervolgens worden de technologien gepresenteerd die een nieuwe en verbeterde vorm van logistiek en supply chain management mogelijk maken. Ze worden herkend als: Internet of Things, RFID, Big Data, machine learning en blockchain-technologie.

Om inzicht te krijgen in het effect van logistiek 4.0 op de havengemeenschap, worden verschillende toepassingen grondig onderzocht. Deze toepassingen zijn: het verplaatsen van de wereldwijde supply chain naar de blockchain, de introductie van slimme containers, de toepassing van op condition-based maintenance op schepen en kranen, de automatisering van terminaloperaties en slimme douanecontroles. Door de wereldwijde supply chain naar de blockchain te verplaatsen, kan de transparantie van de supply chain aanzienlijk worden verbeterd. De introductie van slimme containers zou grote gevolgend kunnen hebben voor status- en positiemonitoring van de lading.

Ook de veiligheid van de container zal toenemen, omdat sensoren kunnen identificeren of een container al dan niet op een onverwacht moment is geopend. Condition-based maintenance maakt gebruik van Big Data en machine learning om onnodig onderhoud te voorkomen door de status van apparatuur te beoordelen en te voorspellen. De automatisering van containerterminals verbetert de operationele efficintie aanzienlijk en maakt snellere operaties en een hogere terminalcapaciteit mogelijk. Slimme douanecontroles gebruiken de verbeterde zichtbaarheid van de supply chain en combineren dit met machinelearning-modellen om het risico van containers te beoordelen. Op basis van deze verbeterde en geautomatiseerde risicobeoordeling wordt besloten welke containers moeten worden genspecteerd en welke niet.

Tot slot worden de uitdagingen onderzocht die nog moeten worden aangepakt voor een succesvolle implementatie van logistiek 4.0 toepassingen. De eerste uitdaging is het gebrek aan wederzijds vertrouwen tussen bepaalde organisaties, voornamelijk tussen de rederijen. Dit gebrek aan wederzijds vertrouwen zou een barrière kunnen zijn voor de verplaatsing van de globale supply chain naar een enkele blockchain, omdat organisaties hun eigen blockchain zouden bouwen. Een tweede uitdaging betreft cyberbeveiliging. Wanneer veel processen worden gedigitaliseerd, worden ze kwetsbaar voor cybercriminelen, hackers of zelfs rivaliserende regeringen. Om logistieke 4.0-toepassingen met succes toe te passen, moeten organisaties een hoog niveau van cyberbeveiliging realiseren. De laatste uitdaging is een sociale uitdaging. De introductie van logistiek 4.0 gaat gepaard met automatisering en daarmee het onvermijdelijk verlies van banen. Deze uitdaging vanuit een ethisch en financieel oogpunt worden onderzocht.

Contents

Contents vi

List of Figures viii

1 Introduction 1

2 Port Community 4
- 2.1 Port Authority . . . 4
- 2.2 Shipping Lines . . . 6
- 2.3 Terminal Operators . . . 7
- 2.4 Freight Forwarder . . . 8
- 2.5 Shipping Agent . . . 9
- 2.6 Third And Fourth Party Logistics Providers . . . 9
- 2.7 Customs . . . 9
- 2.8 Towage & Pilotage Companies . . . 10
- 2.9 Other Players . . . 10
  - 2.9.1 Waste Reception Facitilities . . . 10
  - 2.9.2 Ship Chandler . . . 10
  - 2.9.3 Repair Services . . . 10
- 2.10 Port Community System . . . 10
- 2.11 Summary Of The Port Community . . . 12

3 Logistics 4.0 13
- 3.1 Four Industrial Revolutions . . . 13
- 3.2 What Is Logistics 4.0? . . . 14
- 3.3 Technologies Enabling Logistics 4.0 . . . 15
  - 3.3.1 The Internet Of Things . . . 15
  - 3.3.2 Radio Frequency Identification . . . 16
  - 3.3.3 Big Data . . . 17
  - 3.3.4 Machine Learning . . . 17
  - 3.3.5 Blockchain . . . 18
- 3.4 Summary On Logistics 4.0 . . . 19

4 Applications Of Logistics 4.0 In The Port Community 20
- 4.1 Moving The Global Supply Chain To The Blockchain . . . 20
- 4.2 Smart Containers . . . 23
- 4.3 Condition-Based Maintenance . . . 26
  - 4.3.1 Vessels . . . 27
  - 4.3.2 Container Cranes . . . 28
- 4.4 Automation Of Terminal Operations . . . 29
  - 4.4.1 The Automation Of Container Handling Equipment . . . 31
  - 4.4.2 Terminal Operating Systems . . . 35

4.4.3 Gate Operations . . . 38
4.5 Smart Customs Control . . . 39
4.6 Summary On The Applications Of Logistics 4.0 In The Port Community . . . 40

5 Challenges **42**
5.1 Mutual Trust And Data Sharing . . . 42
5.2 Cyber Security . . . 43
5.3 Social Challenges . . . 44
5.4 Summary On The Challenges . . . 45

6 Conclusion & Recommendation **46**
6.1 Conclusion . . . 46
6.2 Recommendation . . . 48

Bibliography **49**

List of Figures

1.1 Economic importance of the harbor of Rotterdam [3] 1
1.2 Throughput of the port of Rotterdam according to different predictions [4] 2

2.1 Stakeholders in the port community [2] 5
2.2 Size of the largest container ships througout the years [5] 6
2.3 Container terminals in the port of Rotterdam [6] 8
2.4 Schematic side view of container terminal system [7] 8
2.5 Governance model of Portbase [8] 12

3.1 The four industrial revolutions and the technologies that enabled them [9] 14
3.2 A logistics 4.0 framework [10] 15
3.3 Structure of passive RFID system with multiple antennas [11] 16
3.4 Differences between active and passive RFID tags [12] 17
3.5 Principle of the blockchain technology. the "transaction" in this figure is replaceable with "data" [13] 19

4.1 Using the blockchain in the global trade industry [14] 21
4.2 Schematic overview of milestones and documents that could be shared over TradeLens [15] 22
4.3 The architecture of the TREC secure trade line [16] 23
4.4 Communication system architecture proposed by Mahlknecht and Madani (2007) [17] 24
4.5 Container localization technique proposed by Abbate et al. (2009) [18] 25
4.6 Routing tree from containers to the base station [18] 25
4.7 representation of a data driven condition based maintenance framework [19] 27
4.8 Representation of a data driven risk-based condition-based maintenance framework [19] 28
4.9 System design in structural health monitoring of cranes proposed by Li et al. (2013) [20] 29
4.10 Data processing subsystem [20] 29
4.11 Advantages and disadvantages of automated container terminals [21] 31
4.12 Classification of quay cranes by their degree of automation [22] 32
4.13 Rail Mounted Gantry Crane for Automatic Container Stacking [23] 33
4.14 AGV's system and control cycle [24] 34
4.15 Internet of things methodology in a container terminal [25] 35
4.16 Required control activities for managing a container terminal [26] 35
4.17 TOS architecture presented by Singgih et al. (2016) [27] 36
4.18 TOS manager functions presented by Singgih et al. (2016) [27] 37
4.19 Non-Stop Automated Escort and Gate system proposed by Lee et al. (2011) [28] . 39
4.20 Customs risk management system [29] 40
4.21 Scheme of the machine learning project used at Dutch Customs Authorities [29] . . 40

5.1 Classification of different threat actors, their characteristics and their motives [30] 43

Chapter 1

Introduction

It seems difficult to overestimate the importance of international trade in the ever more globalizing world. We eat bananas that were grown in Middle- and South America, use iron ore that was mined in Australia or Brazil, use phones that are mainly produced in China or Vietnam and drive cars that produced in Germany.

Especially in intercontinental trade it is the maritime transport that dominates due to the low cost per kilometer per ton transported and due to the necessity of travelling through sea or air in for instance the trans-Atlantic trade. In fact according to the International Maritime Organization (2013) [1] international shipping transports around 90% of global trade. With seafaring comes the necessity for ports and when the ships become larger and more numerous the ports need to grow along with them and become structurally and logistically more complex.

Not only do ports enable trade, they also provide a large number of jobs either through direct or through indirect employment opportunities. The Erasmus Center for Urban Port and Transport Economics, commissioned by the Dutch Ministry of Infrastructure and Water Management, has researched the economic importance of ports in the Netherlands in terms of employment and added value. Their results are presented in figure 1.1. It is difficult to exactly predict the future growth

	2015	2016	Absolute verandering 2015-2016	% verandering
***Werkgelegenheid* (in werkzame personen)**				
Directe werkgelegenheid	173.966	180.117	+6.151	+3,5%
Indirecte werkgelegenheid	169.394	177.558	+8.164	+4,8%
Totale werkgelegenheid	343.359	357.675	+14.315	+4,2%
Aandeel in economie NL	3,9%	4,0%		+0,1%
Toegevoegde waarde (in euro's)				
Directe toegevoegde waarde	25,04 mld	26,37 mld	+1,32 mld	+5,3%
Indirecte toegevoegde waarde	14,33 mld	14,84 mld	+0,50 mld	+3,5%
Totale toegevoegde waarde	39,38 mld	41,20 mld	+1,82 mld	+4,6%
Aandeel in economie NL	5,8%	5,9%		+0,1%

Figure 1.1: Economic importance of the harbor of Rotterdam [3]

of international trade due to so many unsure factors like the oil price, environmental policies, the slowdown of economic growth in China, trade tariffs being raised by the United States, the rate and extend at which India will become a globalized economy and so forth. The rate of growth may be uncertain, but the direction is not: up. The Port of Rotterdam Authority has, in collaboration with companies in the area, local authorities and national authorities, analyzed four different scenarios and the throughput they expect to be accompanied with them in their Port Vision 2030, this is presented in figure 1.2. These four different economic scenarios, on which their predictions are based, were drawn up by the CPB Netherlands Bureau for Economic Policy Analysis and the European Commission [4].

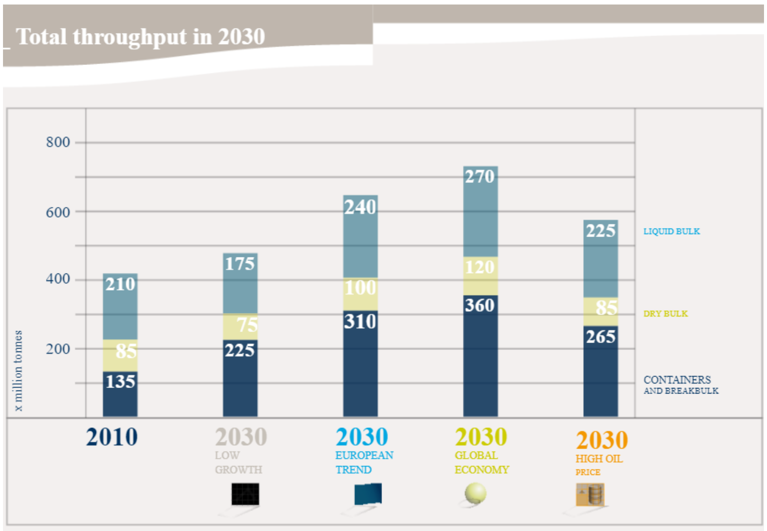

Figure 1.2: Throughput of the port of Rotterdam according to different predictions [4]

The total throughput is expected to rise and especially in containers and breakbulk. In order to meet this increasing demand new physical infrastructure can be built. However, expanding this physical infrastructure goes accompanied with extremely high costs (costs for the second Maasvlakte were close to 3 billion euros [31]) and thus is often not seen as a feasible solution. An alternative to spending large amounts of money on building new infrastructure to increase capacity is investigating on how to improve the use of the existing infrastructure. Another problem is the much heard complaint from shippers regarding the lack of quality of service. McKinsey&Company (2017) [32] conducted a research in which they interviewed many shippers, many of whom were very dissatisfied about the reliability of delivery dates, the transparency of the supply chain and communication when things go wrong. Many of the interviewees said they would be willing to pay extra in exchange for these improvements. In the past years new technologies have been introduced in the manufacturing industry, introducing the concept of industry 4.0. Many of these technologies can also be applied in the logistics industry and in supply chain management, leading to the concept of logistics 4.0. The main purpose of this report is to provide an overview of the concept of logistics 4.0 and to which extent they can be implemented to improve the operational and communication processes in port communities, how this will effect the port community and which challenges must be overcome for a successful implementation. The main question of this literature study is:

What possible applications does logistics 4.0 provide in port communities and how is the port community affected by them?

In order to answer this question as completely as possible the following key questions need to be answered:

1. Which payers make up the port community, what are their goals and which inter-relationships are present?
2. What is logistics 4.0 and what are the technologies enabling it?
3. Which applications of logistics 4.0 are possible in the port community and how do they work?
4. Which challenges are yet to be overcome if logistics 4.0 is to be successfully implemented in port communities?

In chapter 2 the players making up the port community are discussed as well as their goals and the inter-relationships they hold. In chapter 3 the concept of logistics 4.0 and the technologies enabling it are discussed. In chapter 4 various applications of logistics 4.0 in the port community are thoroughly investigated. In chapter 5 the still existing challenges to successful implementation of the logistic 4.0 applications are presented. In chapter 6 a conclusion is given about the previous chapters and how the port community is affected by the introduction of logistics 4.0. Finally, a recommendation for further research is proposed.

This literature review was conducted using the scientific databases Scopus ®, Google Scholar ®, Sciencedirect ®. Furthermore the business magazine McKinsey Quarterly ®and the the website of the Port of Rotterdam Authority were reviewed for technical reports on the current state and future prospects of the maritime industry and for information and the state of the art in port communities.

Chapter 2

Port Community

Port areas are complex structures. In order to understand how logistics 4.0 can affect port communities it is important to understand how they operate, which players have control over which part of the supply chain and which stakeholder are involved. This chapter discusses which players are present in the port community, which roles they fulfill, what their goals are and which interrelationships are present. In figure 2.1 Henesey (2006) [2] maps the stakeholders in the port area and which of those stakeholders are considered to be part of the port community.

The main focus of this report will be on the technical and operational side and therefore the roles of banks, insurance companies and legal firms will fall outside of the scope. Even though logistics 4.0 could certainly have interesting applications for industrial companies such as refineries, time constraints have resulted in them too falling outside the scope of this report. In figure 2.1 shipping lines are not considered part of the port community, but since they own many of the containers and have a major impact on how the port operates they are included in this report. Also since not all ports around the world have the same structure, this chapter will use the port of Rotterdam as a guide. Each subsection in this chapter will present a member of the port community, with the exemption of section 2.10, where the port community system will be presented.

2.1 Port Authority

The port authority is a governmental or quasi-governmental organization, which is usually governed by a commission or board. Brooks (2004) [33] outlines four main port administration models, namely:

- **The service port model** where the port authority owns the land and all assets and performs all regulatory and port functions through labor employed by them. This model is often found in developing countries.
- **The tool port model** where the port authority owns the land and the cargo handling equipment but the port labor is delivered by private cargo-handling firms.
- **The landlord model** where the port authority maintains ownership in the port while the infrastructure is leased to private operating companies. The private operating companies that lease from the port authority provide and maintain their own superstructure, install their own equipment and employ their own dock labor.
- **The private service port** where the port land is owned by the private sector and all regulatory functions and operational activities are performed by private companies.

The port of Rotterdam follows a model closest to the landlord model. The Port of Rotterdam Authority is responsible to develop, manage and exploit the port in a sustainable way and to render speedy and safe services for shipping. De Langen and Van Der Lugt (2017) [34] bring to light that port development is a commercial activity so, even though port authorities are usually state owned, they are run like a company and have quite a level of autonomy. This is necessary because ports compete fiercely with each other for attracting shipping lines and investments in their complex, especially ports that have contestable hinterlands (e.g. Antwerp and Rotterdam).

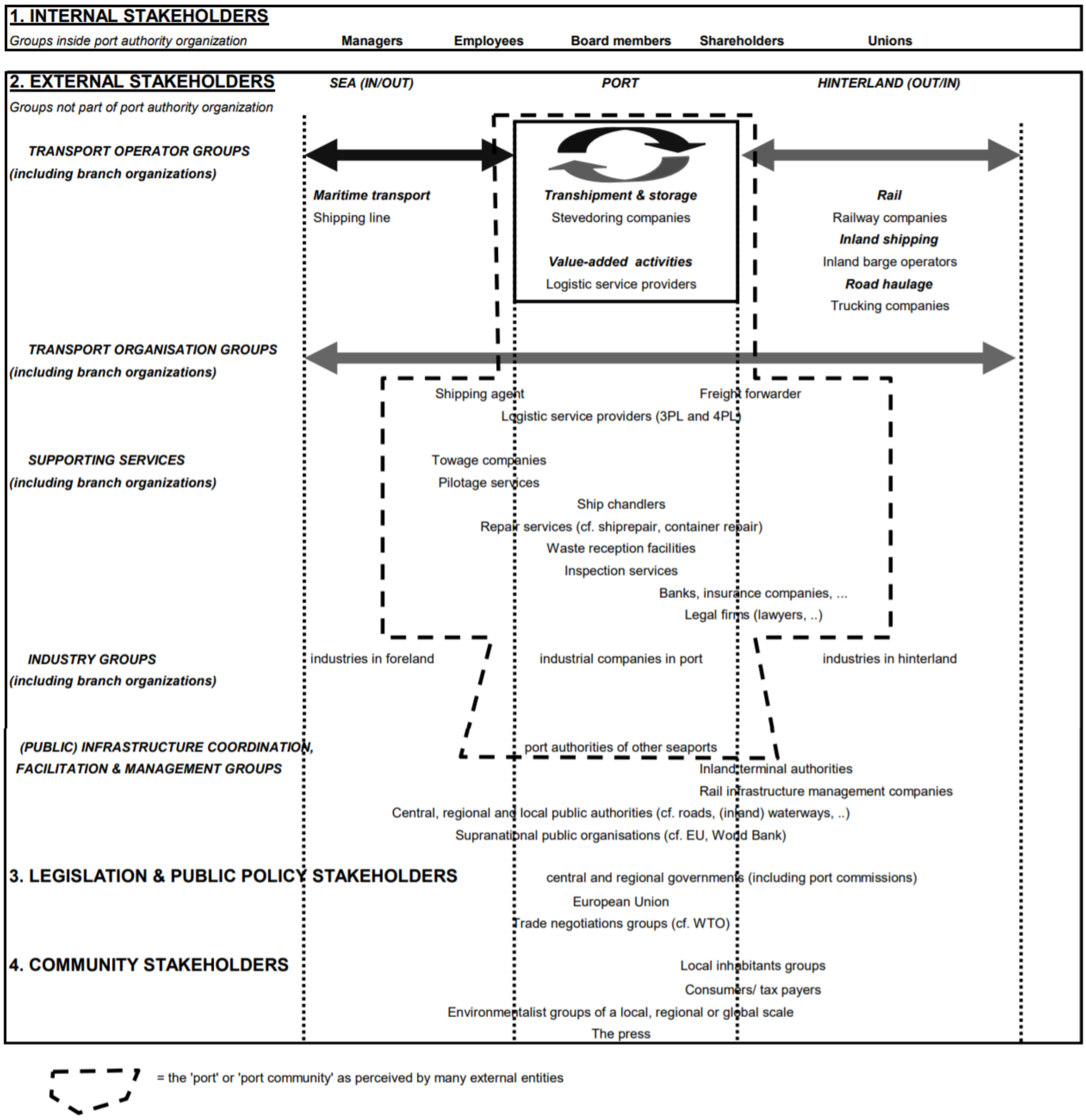

Figure 2.1: Stakeholders in the port community [2]

In land lease choices private companies can put in bids for the port authority to review. When reviewing the bids of for instance, terminal operators the port authority reviews which companies could operate the land in the most efficient way and thus increase general attractiveness of the port area for shipping lines, who lose money when unloading their ships takes too long.

In addition port development includes developing connections in the port area. In order to get an efficient port it is important to retain a good infrastructure and initiatives for the collaborative utilization of the infrastructure. Many ports have also implemented port community systems, which connect all actors in the port environment. The architecture and working principle of port community systems are further elaborated upon in section 2.10.

The Port of Rotterdam Authority is a formally autonomous state-owned corporation that holds the position of the manager and developer of the port and industrial area of Rotterdam. It has two shareholders, the municipality of Rotterdam (71%) and the State (29%), which received its share in return for providing financial resources for the development of Maasvlakte 2.

In Rotterdam the harbor master division also falls under the port authority. This division is tasked with controlling and monitoring the planning and access of all vessels, providing port security and conducting inspections whether vessels comply with shipping regulations concerning environment and safety [35].

2.2 Shipping Lines

Shipping lines are often very large companies who own or lease ships in order to transport goods from port to port. Traditionally shippers or consignees do not care much by which ship or in which container their goods are moved around the world. This has led the shipping business to be very competitive with the shipping lines doing everything in their power to drive down the costs of their operations, in order to earn a profit and to give the shipper a lower price per container transported to remain competitive.

Creating economies of scale and building ever-larger and more economical ships has been the main form of driving down the operating cost per container thus far. Larger ships provide greater cost efficiencies in fuel and crews and reduce greenhouse-gas emissions per container. In 1985 the largest container ship had a capacity of 4,458 TEU whereas the largest ship as of 2017 had a capacity of 21,143 TEU, as can be seen in figure 2.2. The economical effect of building economies of scale is highlighted by Notteboom (2004) [36] who shows that a vessel of 12,000 TEU on the Europe – Far East route would generate a 23 per cent cost saving per container slot compared to a 4,000 TEU vessel.

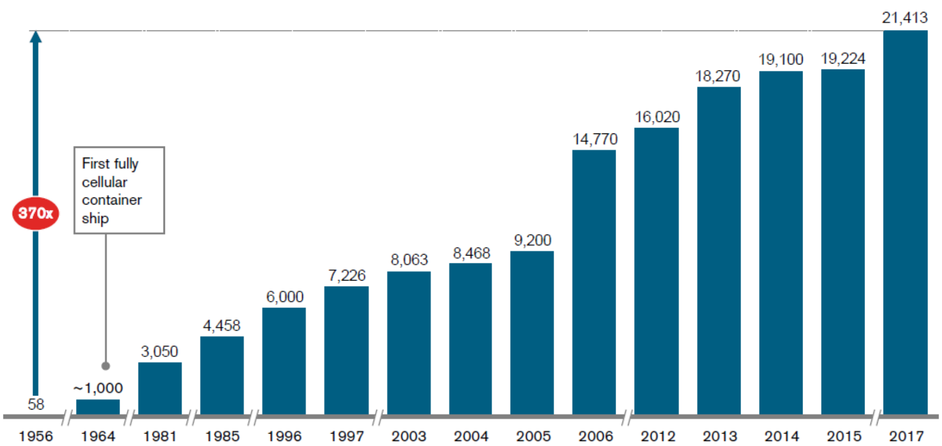

Figure 2.2: Size of the largest container ships througout the years [5]

Larger ships have a lower flexibility than smaller, more frequent ships and are more difficult to fill. They do of course only grant real savings if the vessels are full. This is one of the reasons that shipping lines have created alliances, like the 2M alliance between Maersk and MSC. These alliances share vessels in certain service routes to increase vessel utilization, but also to increase service network, reduce operation cost and improve the market share.

Apart from decreased flexibility and increased difficulty in filling the ships, another disadvantage of large ships is that they complicate terminal operations. In order to service these larger ships terminal operators have had to reinforce their quay walls, extend berths and invest in newer and bigger cranes. Unloading containers from bigger ships takes longer because cranes must reach farther across vessels thus reducing the number of container moves per hour. Another difficulty for the terminal is the fact that larger ships discharge more containers at once, requiring more efficient terminal operations. For shipping lines it is important that port operations run efficiently. The faster they can leave the port again, the slower they can sail, while still arriving on time at the next destination, and thus save fuel costs.

Schedule reliability is of high importance for shipping lines. According to Drewry Shipping Consultants (as cited in Zhang and Lam (2014) [37]) the reliability of container services was around 50 to 60% between 2005 and 2010. Vessel delays lead to significant handling interruption for both the port and the shipping line and usually results in high financial losses. Salleh, Riahi, Yang, and Wang (2017) [38] recognize the main reasons for vessel delay to be uncertainties in port congestion, port inefficiency, poor vessel conditions and rough weather.

As stated in chapter 1 the transparency of the supply chain is a much heard complaint from shippers by the shipping lines. Shipping lines have a vital role in the visibility of the supply chain, not in the least because they often own (or lease) the containers in which goods are shipped.

2.3 Terminal Operators

The terminal operator has the job of moving cargo through a port as efficiently as possible. They manage the movement of cargo containers between arriving and departing ships, trucks and freight trains. Terminal operations could be managed by the port authority but in modern ports they are usually ran by private companies that are leasing the berthing and yard space of ports on long term contracts. They design, construct and operate the terminal themselves and often have contracted with the port authority to reach a minimum level of efficiency, in order to keep the port as a whole as attractive as possible for shipping lines.

Terminal operators compete with each other in making their container terminals as efficient as possible. A higher productivity leads to a shorter time a vessel has to spend in the port, making it more profitable for shipping lines to unload their vessels at that terminal. Voss (2007) [39] recognizes the three most important success factors to attract shipping lines for terminals to be: a short time in ports for ships, low rates for loading and unloading, and reliability.

The port of Rotterdam has multiple container terminals (Figure 2.3), of which all the deep-sea terminals are located at the Maasvlakte. The presence of multiple container terminals is a driver for efficient operations, due to internal competition.

Although seaport container terminals considerably differ in size, function, and geometric layout, they principally consist of the same sub-systems [40]. A container terminal has two external interfaces: the quayside where the containers are loaded/unloaded on/off ships and the landside where the containers are loaded/unloaded on/off trucks and trains. A typical terminal structure is presented in figure 2.4. In between the quayside and the landside lies the container yard where containers are stacked and stored, until they are transshipped again. The quayside uses quay cranes to handle the ships, the containers can be transported between the quay and the stack using various vehicles of which the most common are: the automated guided vehicle (AGV), the straddle carrier (SC) and trucks with trailers. For the container yard management usually either rail mounted

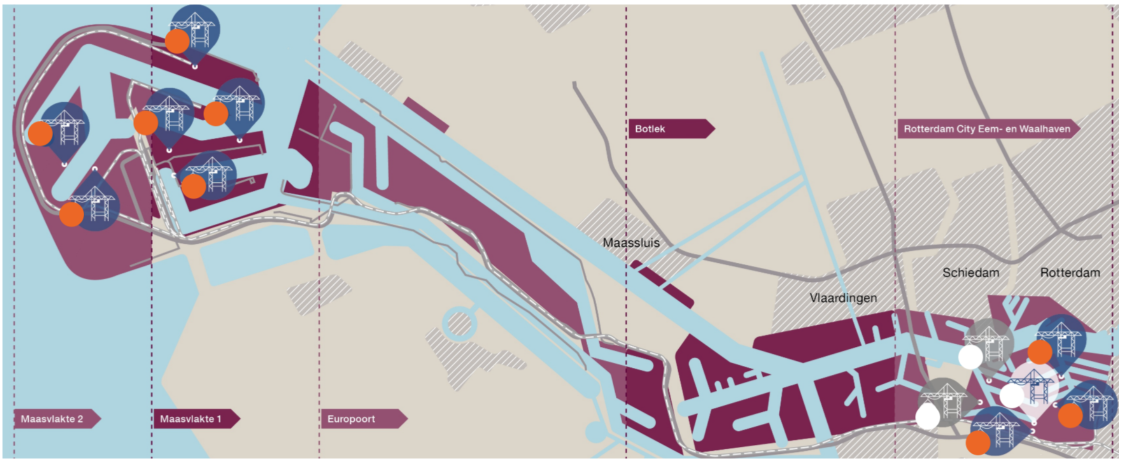

Figure 2.3: Container terminals in the port of Rotterdam [6]

gantry cranes (RMG) or rubber tired gantry cranes (RTG) are used. Specially equipped vehicles such as AGVs, SCs or trucks with trailers can be used for the container transport between the stack and the truck/train operating areas. Train are almost exclusively handled by the RMGs and trucks are handled by RMGs, RTGs or SCs [7]. Due to safety and security regulations all container terminals have an extensive gate system (not depicted in figure 2.4), where the identity of truck drivers and the content of their containers are verified, before they are allowed to enter the terminal. It should be noted that not all terminals use this exact layout. For instance there are also terminals where trucks are unloaded by the stacking cranes in the yard. In this case a special truck lane is laid out next to the stack to handle the trucks.

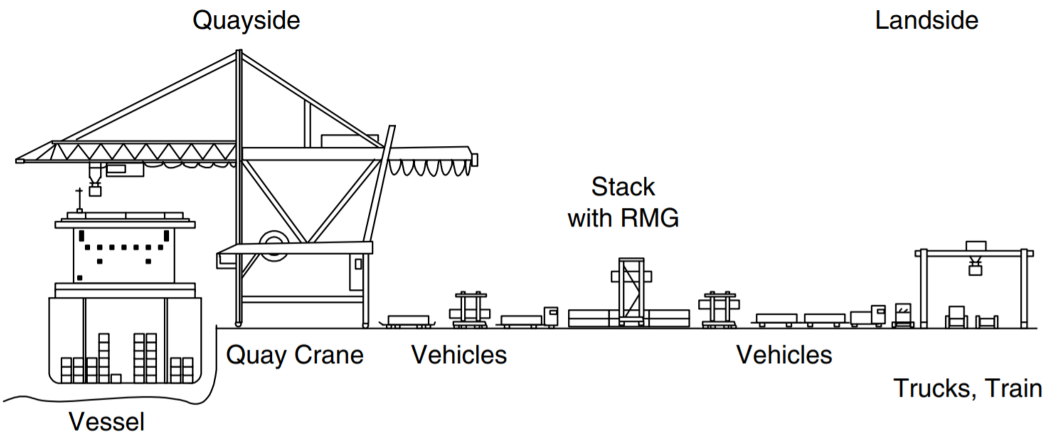

Figure 2.4: Schematic side view of container terminal system [7]

2.4 Freight Forwarder

A freight forwarder is an expert in the logistics network who uses his skills to organize shipments for shippers (i.e. individuals or companies) from one point point to another. The freight forwarder does not move the goods himself but arranges the transportation often utilizing multiple modes of transport using forged relationships with global agents. This allows the shipper to engage in a single contract (i.e. with the freight forwarder) instead of multiple individual contracts with sea-and land transport companies.

Freight forwarders act as travel agents on behalf of shippers, enabling lower rates for shippers through the high volumes of container they move and through the possibility of pooling smaller shipments to fill a shared container. Freight forwarders also deal with the international trade-related documentation, such as the preparing and processing of customs documentation [41]. Other administrative formalities such as the bill of lading or country/product specific import/export documents are also handled by the freight forwarder.

2.5 Shipping Agent

A shipping agent or a shipping agency is the designated person or agency held responsible for handling shipments and cargo, and the general interests of their client ship owners. Shipping agents will usually take care of all the regular routine tasks of a shipping company quickly and efficiently. They ensure that essential supplies, crew transfers, customs documentation, and waste declarations are all arranged with the port authorities without delay and often provide the shipping company with updates and reports on activities at the destination port so that shipping companies have real-time information while goods are in transit [42].

2.6 Third And Fourth Party Logistics Providers

Lieb, Millen and Van Wassenhove (1993) [43] defined third party logistics (3PL) as the following: Third-party logistics involves the use of external companies to perform logistics functions that have traditionally been performed within an organization. The functions performed by the third party can encompass the entire logistics process or selected activities within that process.

So in other words it is the outsourcing of some or all of your supply chain and logistics operations. This does not explicitly entail activities in the port area that are not yet being executed by aforementioned parties in the port community. Therefore it is not further elaborated upon in this report.

The same holds for fourth party logistics (4PL) which Mukhopadhyay and Setaputra (2006) [44] describe as a non-asset based logistics provider, which takes the role of more a strategic partner than a client and has the long-term goal to improve the efficiency of total logistics.

2.7 Customs

Customs is the authority responsible for controlling the flow of goods into and out of a country. Customs authorities around the world are the traditional gatekeepers of both maritime frontiers and international trade. Customs offices aims to carry out the statutory checks with a minimal impact on the logistics process. The Port of Rotterdam acts as an external border of the European Union, which means that, after clearance in Rotterdam, freight can travel freely through the EU member states.

As Chalfin (2007) [45] explains, one way customs authorities manage the huge volume of commerce without disrupting the logistics process is through the requirement that all entry information be received prior to a ships' arrival at the port. At Rotterdam, a declaration of all goods on board originating outside of the EU must be submitted through electronic means at least 4 hours before arrival at the port [46]. This gives customs time to evaluate the tremendous volume of cargo entering the port and preempt the entry of dangerous goods.

Customs uses a risk management system (RMS) to handle the declaration documents of goods and to assess their associated risk. On the basis of this customs can decide whether to clear, detain, reject or inspect cargo prior to the actual arrival of goods at the port. In Rotterdam inspections are performed using on-site scans after which images are analyzed and a decision is made whether or not a physical inspection is required.

2.8 Towage & Pilotage Companies

Towage companies use tugboats to maneuver other vessels that are restricted in their ability to berth on its own. Large container ships have a huge turning radius which usually does not allow them to moor at a berth located in a port. In smaller ports it is more efficient to have a single provider of towage [47], which leads to a natural monopoly, resulting in more expensive and less efficient operations. In order to keep their ports as attractive as possible for shipping lines, port authorities of larger ports avoid these situations and promote a certain level of competitiveness amongst towage companies. In Rotterdam there are three towing companies that offer services to large vessels [48].

Although ship captains have great expertise at navigating their vessels, they do not have that same expertise on the very specific environments of the ports at which their vessel calls. For this reason a locally experienced pilot, arriving by helicopter or boat, takes over control of the ship. The pilot gets assisted by tugboats owned by a towage company to get the vessel safely and efficiently to the berth. Due to the very serious consequences accidents would infer (e.g. blocked channels) most ports have compulsory pilotage for large ships. In the port of Rotterdam there is only one pilotage company, since the skill and expertise of pilots should be safeguarded. In order to keep the costs for shipping lines within check the rate structure of the pilotage company has been consulted with the port authority.

2.9 Other Players

2.9.1 Waste Reception Facitilities

Under international legislation all seaports are obliged to facilitate adequate waste reception facilities for ships' waste. Port reception facilities can collect ships' waste by means of mobile collecting facilities (vessels or vehicles) or fixed facilities (storage tanks) [49].

2.9.2 Ship Chandler

A Ship chandler is a retailer for supplies and equipment for ships. These supplies are ordered in advance. Many and sometimes heavy engine parts can be ordered by the shipping line and stored by the chandler in anticipation of the ships' arrival, after which they are delivered by boat.

2.9.3 Repair Services

Most ports have repair services to provide maintenance for damaged parts. The port of Rotterdam has a drydock for serious damages, but there are also several diving companies to perform quick inspections or repairs at the buoys and dolphins of vessels [50].

2.10 Port Community System

The performance of port authorities, shipping lines, terminal operators, customs and other organizations in carrying out their supply chain activities largely depend on their collaborations. The efficiency of the flow of information (e.g. customs documents, bill of lading) and goods (e.g. containers) is highly interdependent, which causes a lot of coordination challenges between organizations [8]. In many ports the flow of information is transferred through phone calls, faxes and e-mails which cause delays and large paper trails. To address these challenges and to improve the efficiency of the port, a port community can be supported by a Port Community System (PCS), which is an electronic platform that connects members of the port community. All members of the port community can access the PCS to share documents and data in an efficient manner. Members of the PCS can thus access relevant data, improve efficiency and reduce paperwork. Di Vaio, Varriale and Alvino (2017) [51] point out that still relatively few seaports worldwide have implemented a PCS (i.e, UK, Germany, Spain, Belgium, France, China, USA, Netherlands, Singapore, South Korea).

Portbase is the combined PCS of the ports of Rotterdam and Amsterdam. The ownership is shared between their port authorities. Some of the members of Portbase include: port authorities, shipping lines, terminals, customs, barge operators, exporters, importers, freight forwarders and rail infrastructure managers. A more elaborate and schematic view of the governance structure of Portbase is given in figure 2.5. Portbase offers forty different services subdivided in four domains [52]:

1. Ships' calls
2. Import cargo
3. Hinterland transport
4. Export cargo

Ships' calls includes services for agents, shipping lines, authorities and waste reception facilities such as the notification of dangerous goods from shipping lines to the harbor master. Another service in this regard is the notification of waste disposal, which allows ships to notify waste disposal services of the waste materials they have on board.

Import cargo services help agents, shipping lines, terminal operators, importers and forwarders to import more efficiently. Some of the services include offering an electronic platform for uploading the cargo information from shipping lines to customs and uploading a container discharge list from shipping lines to container terminals.

The hinterland transport services are for the road, barge and rail sectors. An example is the barge planning service which lets barge operators make appointments with container terminals about their arrival and discharge list more easily.

Export cargo services for forwarders, exporters, agents, shipping lines and cargo handling agents are for handling export formalities. One example is the loading list service which offers an electronic platform that lets shipping lines send their loading lists to the container terminals more easily.

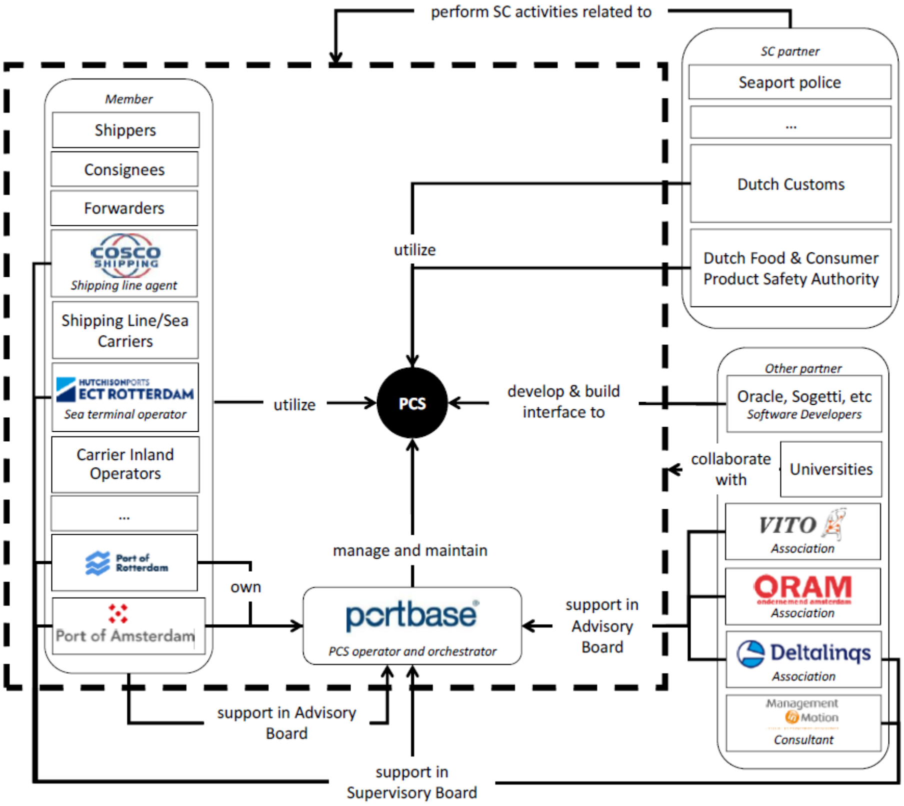

Figure 2.5: Governance model of Portbase [8]

2.11 Summary Of The Port Community

In this chapter the first key question: " *Which payers make up the port community, what are their goals and which inter-relationships are present?*" has been answered. The first player is the port authority, which aims at making their port area as attractive as possible for industry and for shipping lines. The shipping lines transport cargo from port to port and aim to spend as little time in port as possible, since fuel costs are a large fraction of their operating costs. A second aim for the shipping lines is improving the supply chain transparency to please their shippers. The terminal operators perform a transshipment of cargo between the shipping lines and the hinterland. Terminal operators aim to make themselves attractive to shipping lines, to secure their business. Therefore it is necessary for terminal operations to run as efficiently as possible in order to remain competitive with neighbor terminals. Freight forwarders want to move as much cargo as they can since contracts with shippers is their basic source of income. They benefit from an intransparent supply chain since they would become obsolete if shippers could easily organize the entire transport process themselves. Shipping agents usually act as the middleman between ships and the port community. If communications between ship and shore become easier and more transparent, they too risk becoming (at least partly) obsolete. Customs aims to have control and knowledge over the flow of goods that enter and leave the port, while hindering the logistic processes as little as possible. Customs cooperates and communicates with the shipping lines, whose containers' risk are assessed, and with the terminal operators, since the containers selected for inspection are to be moved from the terminal to the inspection site. Towage and pilotage companies, waste reception facilities, ship chandlers and repair services provide services to ships entering and exiting the port. It can be concluded that an efficiently operated and well-structured port community is beneficial to all its members.

Chapter 3

Logistics 4.0

Chapter 2 presented the players that make up the port community, their goals and their interrelationships. This chapter starts with a look at the introduction of technologies in the previous centuries and how they sparked their respective industrial and logistical revolutions. Secondly, the concept of logistics 4.0 is discussed and what it aims to achieve. After this the technologies that enable logistics 4.0 to achieve these aims are elaborated upon one by one. This chapter concludes with a short summary on the aforementioned subjects.

3.1 Four Industrial Revolutions

In the second half of the 18th century the first industrial revolution took place in England and later in the rest of Europe and the United States. The transition from manual production to mechanized production, the introduction of the steam-engine powered by the massive extraction of coal and the development of new machine tools all led to a massive increase in productivity. The first industrial revolution also improved the transportation infrastructure through the introduction of the rail network. Goods and people could be moved more quickly and cheaply than before.

At the end of the 19th century, the second industrial revolution was characterized by the electrification of production systems and mass production through the introduction of the assembly line. The means of communication were revolutionized by the successive inventions of the telegraph and the telephone, as well as the means of transport with the appearance of the automobile then the plane at the beginning of the 20th century.

The third industrial revolution (also named the digital revolution) took place in the second half of the 20th century. The invention of the transistor and the microprocessor opened the door for the computerization and automation of production processes and of course for the introduction of the internet. Due to these introductions information could flow easier and faster than ever before.

In 2011 in Germany during the Hannover Fair Event the concept of Industry 4.0 was introduced, symbolizing the beginning of the fourth industrial revolution. Catalysts for the fourth revolution are the astonishing rise in data volumes, computational power, connectivity and a set of new (some newer than others) technologies and concepts which, when brought together, have the potential to permanently disrupt many industries, as we know them.

Even though the initial focus of industry 4.0 was on the manufacturing industry, it is now realized that many of these technologies can also be applied in the logistics industry and in supply chain management. This new form of logistics and supply chain management in the context of industry 4.0 has been labeled logistics 4.0.

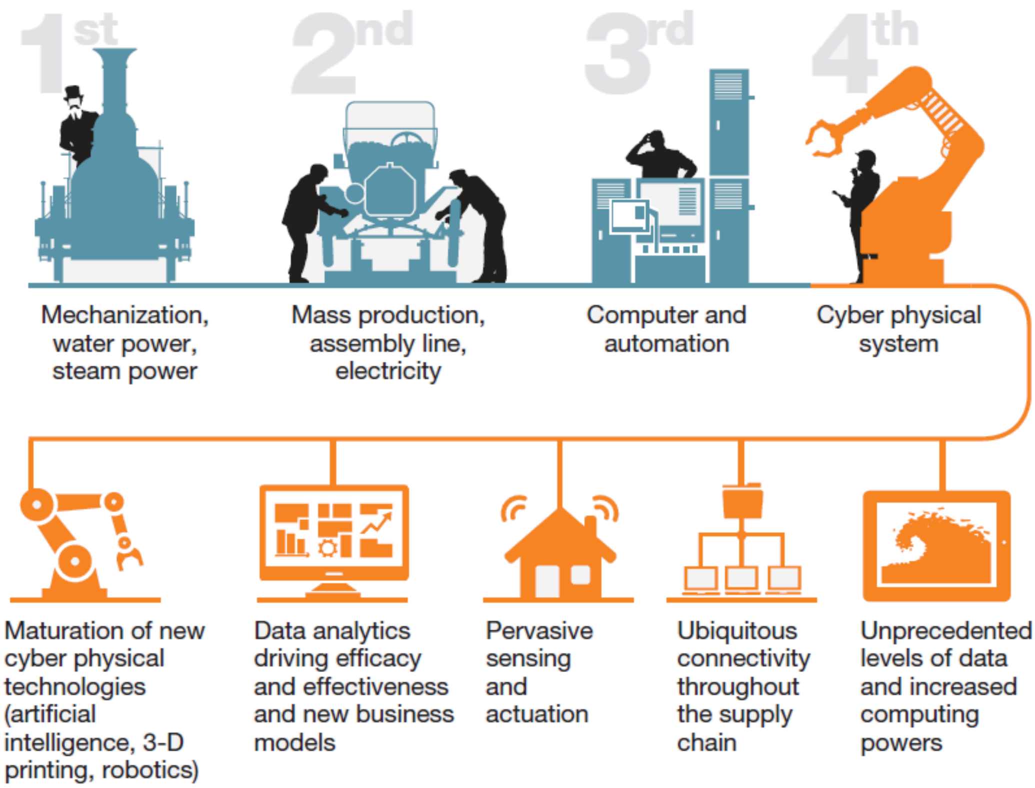

Figure 3.1: The four industrial revolutions and the technologies that enabled them [9]

3.2 What Is Logistics 4.0?

There is no clear definition of logistics 4.0 [10]. It is not defined where logistics 4.0 begins and where it ends, as well as which technologies fall inside the framework of logistics 4.0 and which do not. However, it is agreed upon that logistics 4.0 combines two aspects: processual (supply chain processes are a subject of the Logistics 4.0 actions) and technical (tools and technologies that support processes in the supply chains) [53].

Usually traditional supply chains lack both timely and correct information and have problems coping with unexpected or unplanned events [54]. The processual and technical aspects of logistics 4.0 aim to reduce complexity, increase reliability and transparency, minimize risk, reduce errors, reduce transport and handling costs and increase flexibility in the processes [55].
Olekw-Szapka and Stachowiak (2019) [53] list the three main aspects of logistics as:

1. Management
2. Flow of material
3. Flow of information

These key logistic activities are set to be affected by the introduction of logistics 4.0. Management concerns the need for managers to be aware of logistics 4.0, to be willing to invest in these solutions and to integrate them in the logistic and supply chain process in a good way.

The flow of material concerns itself with the automation of the transport process. Autonomous vehicles and autonomous handling equipment are central terms in this aspect.

The flow of information is the third aspect of logistics and is set to be affected the most by the introduction of logistics 4.0. Improving supply chain visibility and connectivity is key here. By giving goods a 'virtual twin', equipping them with sensors and providing ubiquitous connectivity unprecedented levels of data are created. This data can be used to monitor the status and position of the goods and to track them throughout the supply chain, allowing for a much higher transparency [56]. Also a more extensive information flow could be established between equipment and other equipment to improve operational efficiency. A more extensive information flow could also be established between equipment and control systems in order to monitor the status and productivity of equipment. Increased computing power and data analytics make large sums of data transmitted by all parts of the logistics network more valuable than before, as the information in the data can be processed and analyzed more efficient than before.

A depiction of a logistics 4.0 framework is presented by Hofmann and Rüsch (2017) [10] in figure 3.2. It is shown that customer value can arise from an improvement in the physical supply chain (e.g. through automation). Customer value can also arise from digital integration, allowing a more transparent end-to-end supply chain. Finally customer value can arise from potential value-adding services, resulting from analyzing the gathered data.

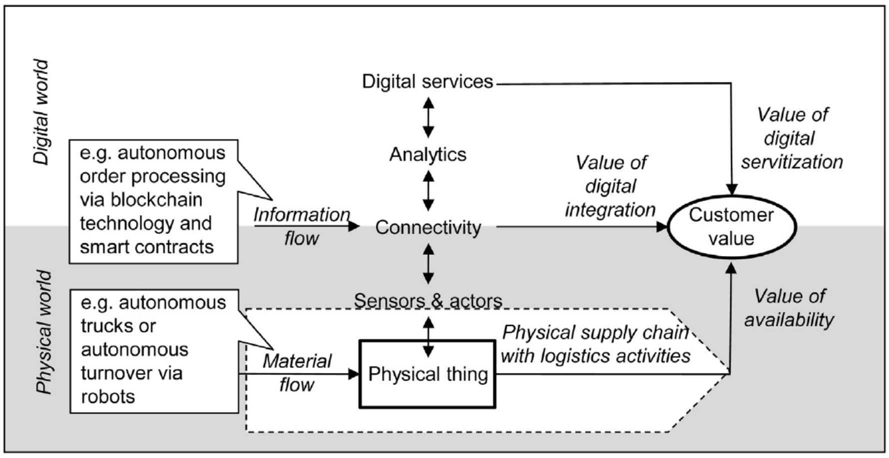

Figure 3.2: A logistics 4.0 framework [10]

These new processes, the better communication and better utilization of information are enabled by the introduction of technologies in the logistics and supply chain processes. These technologies are presented in the next section.

3.3 Technologies Enabling Logistics 4.0

As mentioned in the previous section, it is not exactly defined where logistics 4.0 begins and where it ends, as well as which technologies fall inside the framework. The most named technologies in the literature are elaborated upon in this section and are the Internet of Things, RFID, Big Data, machine learning and blockchain technology [14, 10, 54, 57].

3.3.1 The Internet Of Things

The internet as we know it has succeeded in connecting humans all over the world using connected devices such as phones and laptops. The Internet of Things (IoT) promises an interconnection between many of the objects that surround us. As stated by Giusto, Iera, Morabito and Atzori (as cited in Atzori, Iera, and Morabito (2010) [58]) the basic idea of the concept is the presence around us of a variety of things or objects, which through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals.

The Cluster of European Research Projects on the Internet of Things [59] defines things as active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information sensed about the environment, while reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention.

So in short, the Internet of Things is the network of physical objects, with sensors and/or actuators embedded in them, linked through wired or wireless networks, that communicate and cooperate with each other.

3.3.2 Radio Frequency Identification

One of the most used components in IoT networks is the RFID tag. RFID stands for Radio Frequency Identification and RFID tags help in the automatic identification of anything they are attached to, and act as an electronic barcode. An RFID system consists of at least one RFID tag and one reader. An RFID tag is made up of a chip that stores the tags unique serial number and an antenna that receives external power from an RF wave transmitted by the reader, and transmits the data stored in the chip to that reader using that same antenna.

RFID tags can be subdivided into passive, active and semi-passive tags. The most common are the active and passive tags and the difference between them is summarized in figure 3.4. Passive RFID tags do not need an on-board power supply because they harvest power from the RF signal transmitted by the reader as explained above. Usually the gain in passive tags is quite low, resulting in a smaller reading range. The fact that no on-board power supply (i.e. battery) is needed results in a lower cost and no required maintenance (i.e. replacing the battery). A possible structure for a passive RFID system with multiple antennas is given in figure 3.3.

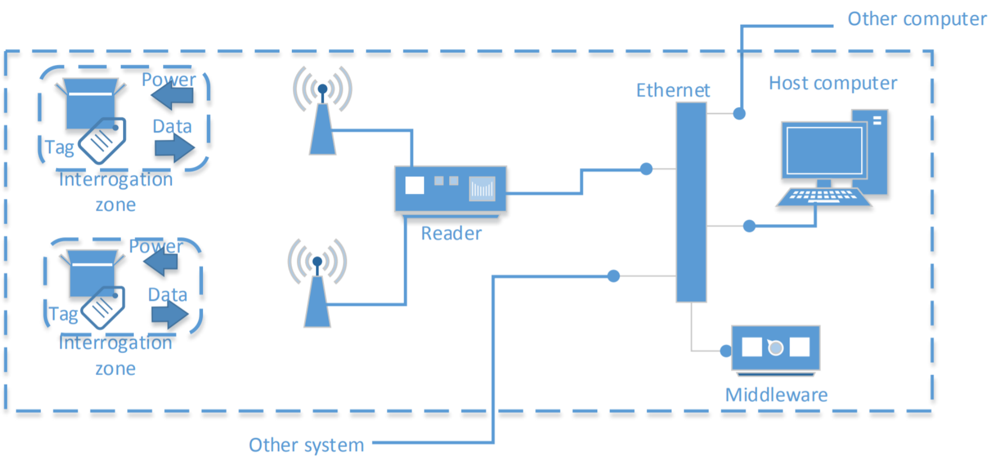

Figure 3.3: Structure of passive RFID system with multiple antennas [11]

Active RFID tags have their own power supply to provide necessary energy to actively and periodically communicate the stored information to the reader. This results in a larger reading range, but since a battery is required the active tag is more expensive, has a bigger size and needs maintenance when the battery has run dry. The semi-passive tag works on the same principle as the passive tag, but it has an internal power supply which increases the range of the tags response.

In short RFID can automatically identify and track objects through the attached tags, which contain electronically stored information. Unlike a bar code, the reader needs not to be within the line of sight of the tag. For instance fixed RFID readers in the supply chain are able to identify all the goods that pass them. After this the position of the goods can be automatically updated and shared among the entire supply chain.

	Active RFID tags	Passive RFID tags
Tag power source	Internal to tag	Energy transferred from the reader
Availability of tag power	Continuous	Only when found in the field of the reader
Required signal strength from reader to tag	Low	High
Available signal strength from tag to reader	High	Low
Communication range	Long range	Short range
Multi-tag collection	Scanning of thousand of tags from a single reader Scanning of up to 20 tags moving at more than 100 miles/hour	Scanning of a hundred of tags within 3 meters from a single reader Scanning of 20 tags moving at 3 miles/hour or slower
Sensor capability	Ability to monitor continuously monitor sensor input	Monitor sensor input when tag is powered from the reader
Data storage	Large	Small

Figure 3.4: Differences between active and passive RFID tags [12]

3.3.3 Big Data

The development of the Internet of Things is paired with huge amounts of information being produced, transmitted and collected. The processing and analyzing of such a large flow of data is beyond the capabilities of traditional tools. A technology that does allow for this is called Big Data. As Witkowski (2017) [57] explains Big data allows us to quickly and efficiently manage and use this constantly growing database, through analysis and separation of the important from the less important. Witkowski names the 4 V's which define Big Data:

- Volume (amount of data) - the volume of the data stream is so large that ordinary tools for collection, storage and analysis are not able to manage it.
- Variety (variety of data) - Big Data comes from a variety of sources, such as sensors in IoT objects but also from social media, weather forecasts etc. They also hold a variety of forms (e.g. images, videos, sensor output).
- Velocity (speed of generation of new data and analysis) - data analysis is carried out on Big Data in near real time, as the correct conclusions from the constantly flowing and changing data need to be implemented on an ongoing basis.
- Value (value of data) - the general aim is to isolate the whole mass of information to what is most important for us, which is why it is important that the results reflect the actual conditions.

So in short Big Data makes it possible to process, store, analyze and access all the data, which leads to useful insights and thus to more efficient operations.

3.3.4 Machine Learning

Machines have already automated many aspects of human society. However, machines have to be programmed which causes difficulties. Some tasks are too complex to program, for instance how would you program a machine to understand images or to recognize speech? A second problem is the fact that the required task can change over time and since traditionally programmed tools remain unchanged after being written, this causes problems and would require tools to be rewritten too often to make it worthwhile.

Humans learn these hard-to-program basic traits, such as speech recognition, through experience: after hearing words and phrases many times we start to understand their meaning. In many cases learning is the process of converting experience into knowledge. In order to make machines capable of performing tasks such as these, learning algorithms are developed where the input is training data, representing the experience, and the output is the expertise gained from this knowledge. This experience takes the form of a computer program that is able to perform a certain task, such as speech recognition [60].

Once this (ever increasing) expertise has been gained through the machine learning algorithms, computer programs not only have the ability to mimic human intelligence (e.g. the ability to recognize images etc.), but it can perform tasks beyond human capabilities. Its great computing power would represent a tremendously fast working brain and its almost unlimited storage space would serve as a flawless memory, allowing it to for instance, analyze huge datasets and detect patterns and useful information from them, that the human mind would be unable to do. An impressive example of the strength of learning machines is presented by Esteva et al. (2017) [61] who trained a machine with 130,000 images to recognize skin cancer from clinical images. This machine performed on par with a team of 21 certified dermatologists.

3.3.5 Blockchain

A blockchain provides a distributed, transparent, immutable and secure ledger which records all the (data) transactions made by the members of the network [62]. It is replicated and shared among all its members. This means that the data is decentralized and each member of the network can read the data stored on the blockchain [63], and thus create a single version of the truth with which all the members agree. In the blockchain each piece of data-input can be checked and traced, resulting in a very high level of transparency. The way that a blockchain is built makes it extremely difficult to cheat the system.

Each block in the blockchain contains some data, the hash of the block and the hash of the previous block, as presented in figure 3.5. A hash is like a fingerprint and it is always unique, it identifies a block and all of its stored data. Because the hash of the previous block is also stored in each block, a chain is created, linking all blocks to its neighbors in the chain. If someone tries to commit fraud and alter the data in a block, it causes the hash of that block to change. This would make the block coming after the altered block invalid, since its hash of the previous block would not be the same as the (new) hash of the altered block and the chain would be broken. He would then need to recalculate all the blocks that came after the altered block, which is computationally very challenging. On top of this blockchains use a distributed network with multiple nodes who all have a full copy of the blockchain. If a new block is created (new data needs to be stored), each of these nodes have to verify that the newly created block is indeed correct and that it has not been tampered with. If more than 50 per cent of the nodes in the network agree that the newly added block is correct, consensus is reached and it is accepted as the single version of truth, and added to every node's blockchain. This means that in order to cheat the system, someone would need to recalculate all the blocks after the altered block and convince all the peers in the network that his version of the truth is the correct one. This makes it nearly impossible to alter previously entered data. The distributed nature of the blockchain also protects it from hackers, since a he would need to hack over half of the nodes in the network, which seems highly improbable [1].

[1] The goal of this section is to give a general overview of blockchain technology. For more information on how new blocks are created or consensus is reached I suggest [64]. It should be noted that not every blockchain uses the same set of rules for this

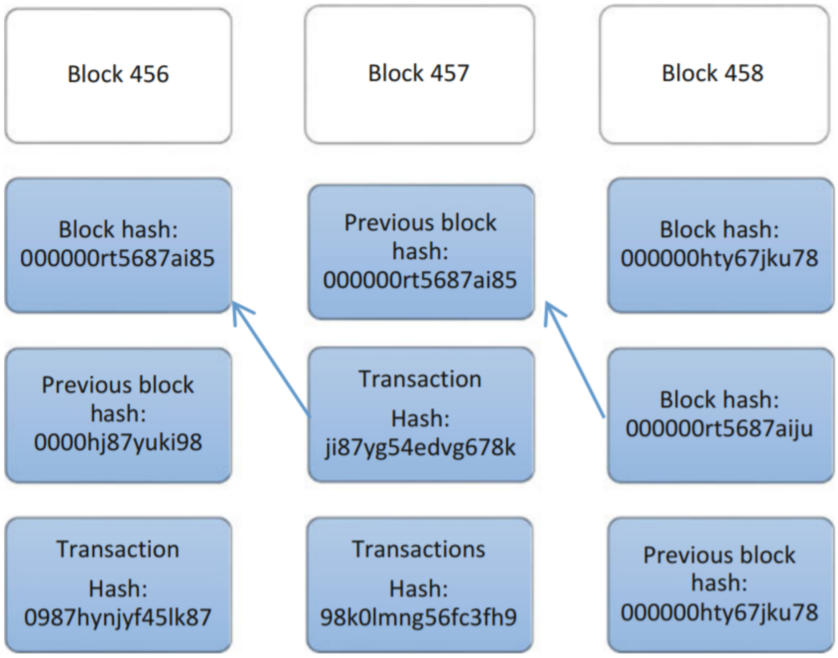

Figure 3.5: Principle of the blockchain technology. the "transaction" in this figure is replaceable with "data" [13]

3.4 Summary On Logistics 4.0

In this chapter the key question: "*What is logistics 4.0 and what are the technologies enabling it?*" has been answered. New technological advances have spurted new ways of conducting business in the logistics and supply chain industry. These new ways are merged in the term logistics 4.0. Logistics 4.0 centers around the automation of the handling and the flow of materials and of information. The key goals are increasing reliability, transparency and flexibility, and decreasing complexity, risk, errors and transport costs. Technologies such as RFID and the Internet of Things are connecting goods and equipment with their environment and generate enormous amounts of data in the process. The introduction of Big Data allows this data to be processed, stored and analyzed. The information in this data can give many new insights concerning the logistical processes and operations. Machine learning techniques are automating tasks, which could previously not be automated, through the analysis of huge data sets. This allows for the first time the automation of knowledge workers. Finally the blockchain provides an immutable and transparent ledger to record data. The blockchain provides a single source of truth, which cannot be tampered with, thus increasing (or taking away the need of) trust between organizations.

Chapter 4

Applications Of Logistics 4.0 In The Port Community

Chapter 2 discussed the players that make up the port community, their goals and their interrelationships. Chapter 3 introduced the concept of logistics 4.0. Its principles were outlined and the technologies forming the cornerstone of this new way of operating in the logistics industry were documented. The aim of this chapter is to integrate logistics 4.0 with the actors in the port community. This chapter will detail how the operations of various members of the port community can be improved by implementing logistics 4.0. This will be illustrated with several concrete examples.

4.1 Moving The Global Supply Chain To The Blockchain

Global trade is highly inefficient. Maersk Line did a number of pilots and found that a single shipment of avocados from Mombasa to Rotterdam involved over 30 actors (e.g. customs, tax officials, health authorities etc.) and over 200 information exchanges, often still with paper-based processes and cumbersome peer-to-peer messaging [65]. A second pilot tracked goods from Central Europe to the Unites States and found containers being delayed for 4 weeks due to missing customs documents. The required customs documents were not communicated clearly between US customs and the exporter. The supply chain is slowed by the volume and complexity of point to point communications. Furthermore, a shipper or freight forwarder may have to make up to five calls to different parties in order to locate his/her container. Among other things this is a result from data being trapped in organizational silos. Finally, fraud is a frequent occurrence in global trade. The bill of lading of containerized goods is often tampered with or copied, resulting in billions of maritime fraud every year [66].

In order to tackle these problems IBM and Maersk Line have jointly developed TradeLens, which applies blockchain technology to the global supply chain. TradeLens is an open and neutral platform, running on blockchain technology and is already being supported by major players across the supply chain, such as port authorities, terminal operators, customs authorities and other ocean carriers. TradeLens has the goal of connecting all parties in the supply chain and of creating a secure platform for the sharing of real-time supply chain information. It encompasses shipping milestones, customs filings, cargo details and more, see figure 4.2. In this way TradeLens provides end-to-end supply chain visibility where all the transactions and documents are saved on the shared blockchain ledger, allowing different actors to track data in a secure way and creating a single version of truth [67]. Apart from being an immutable and transparent ledger, TradeLens could be used to trigger certain actions in response to other activities. For example, when a container is sealed an automatic notification could be sent to the terminal operator, allowing it to prepare for the container's arrival. TradeLens works with a distributed, permissioned blockchain.

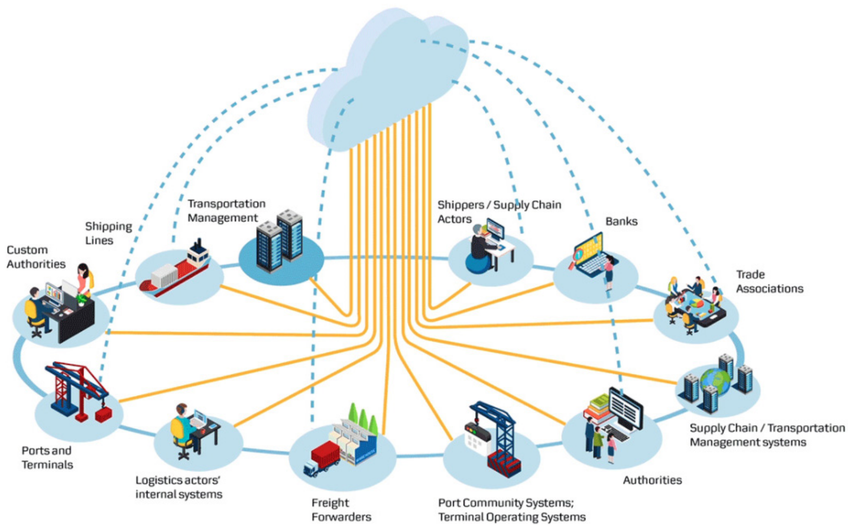

Figure 4.1: Using the blockchain in the global trade industry [14]

This means that only the parties participating in a specific shipment have access to it, ensuring a certain level of privacy for participating parties and respecting confidentiality [68]. There are clear benefits to shippers and freight forwarders, who are now able to retrieve more reliable information in less time. Customs has quick access to reliable information on each container's entire shipment lifecycle, which can be used for better risk-assessment in deciding which containers to inspect. A container which has been in Colombia might have a higher chance of containing illegal narcotics than a container originating from Japan. Actions such as a container breach (noted by the container seal) will upload this information directly to the blockchain, thus informing customs that the container has been opened for an unknown reason, and thus this container should be inspected at arrival in port. Terminals have access to more reliable information about container's next location, allowing them to optimize stack placement. Terminals also have access to more reliable information about a container's estimated time of arrival at the gate, or a vessel's estimated arrival at the port, allowing them to make preparations. Shipping lines are able to offer their customers a more transparent supply chain. Apart from offering their shippers a better service, this also means fewer customer phone calls and emails to customer service, since shippers can easily access the status of their goods themselves. In case of a dispute there is a single source of truth and possible delays or mistakes can be traced back in the immutable records of the blockchain. Port authorities are fixed on making their port as efficient and attractive as possible and thus too have much to gain from a system such as TradeLens. Finally, since documents such as the bill of lading are recorded on the blockchain it is impossible to tamper with them, thus eliminating the huge costs associated with fraud.

One could rightly point out that TradeLens and Port Community Systems, as presented in section 2.10, have an overlap in certain functions. This could cause a potential conflict of interest, since the board of Port Community Systems such as Portbase might oppose the introduction of TradeLens. However, Portbase is owned by the port authorities of Rotterdam and Amsterdam, like other Port Community Systems are owned by their perspective port authorities. It is the objective of a port authority to make their port as competitive and as attractive to shipping lines and industry as possible. Thus it lies in the line of expectation that they would not oppose the introduction of new systems, as it would give other ports with contestable hinterlands a competitive edge over their own. It is most likely that these certain services offered by both TradeLens and the PCS would cease to exist on the PCS, since TradeLens offers an end-to-end service and organizations usually prefer to use a single platform for all operations.

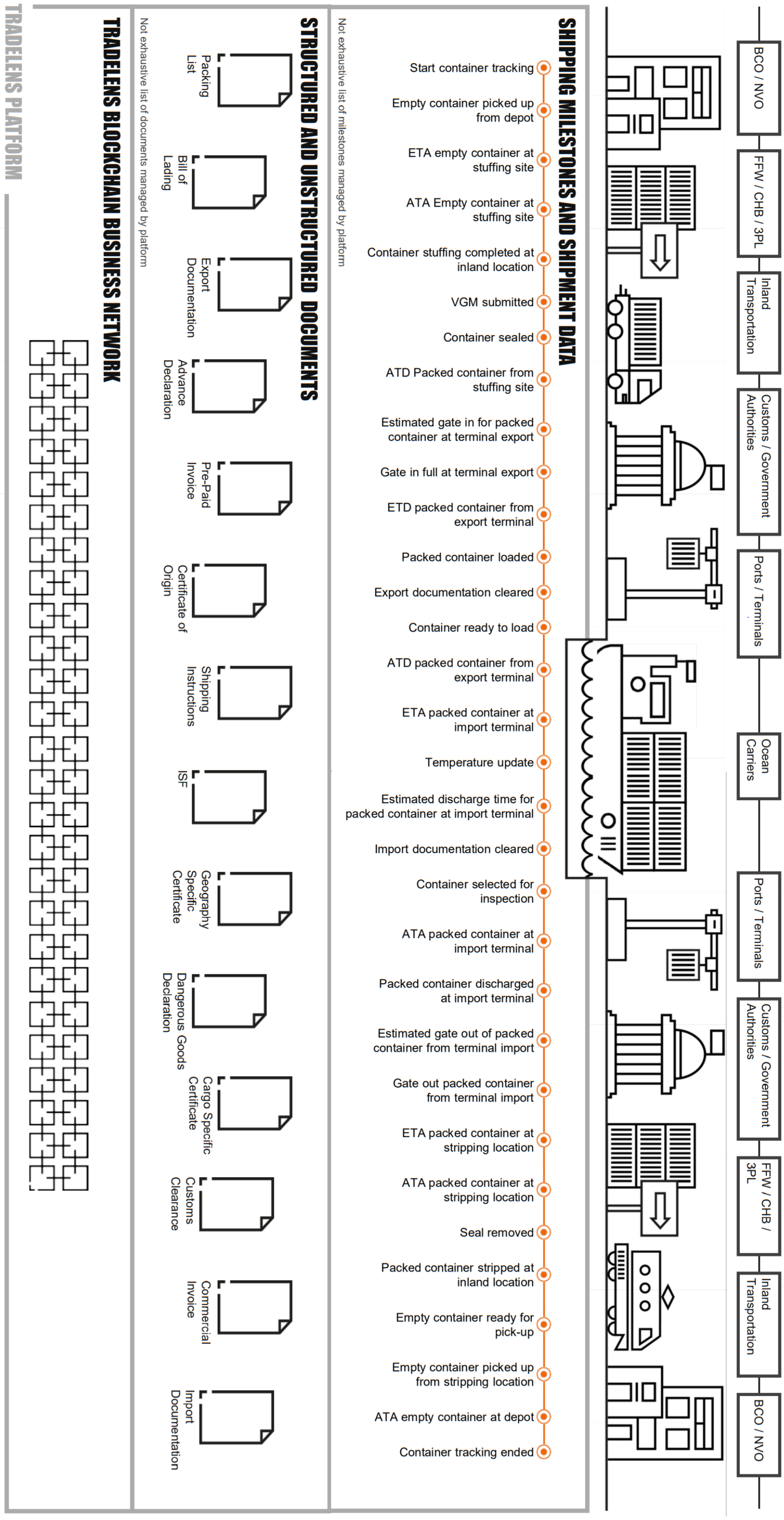

Figure 4.2: Schematic overview of milestones and documents that could be shared over TradeLens [15]

4.2 Smart Containers

One of the most promising applications of logistics 4.0 in the international freight industry is the smart container. Since most containers are owned by the shipping lines (some are owned by container-leasing companies), this application most likely falls under their responsibility. Container terminal operators, customs, shippers and hinterland transport have much to gain from the smart container as well however.

Improved supply chain visibility and enhanced security are key drivers for the development of the smart container. In order to achieve this Schaefer (2006) [16] lists the following requirements: the continuous monitoring of container integrity (e.g. door openings), the determination of the container location with high accuracy, the monitoring and storing of climate conditions (such as temperature and humidity) and shock data (using accelerometers), the sending of alerts in real-time in case of an incident, a secure data storage so that only authorized parties are able to read it and a very long battery life for electronic components so that battery replacement does not require too much maintenance, all whilst keeping the solution at an acceptable price due to the shipping industry's sensitivity to pricing.

The solution presented by Schaefer (2006) [16] is depicted in figure 4.3. The Tamper Resistant Embedded Controller (TREC) is mounted at a container door and comprises of a set of sensors of your choice, processors, data storage and wireless radio. These sensors can detect door openings, temperature, acceleration, humidity and position (through GPS). The TREC collects the data and turns it into relevant information, through filtering, aggregating and correlating it. The TREC can also hold supply chain data such as a bill of lading. A Smart Card is used for data security and also provides the ability to separate data spaces, i.e. making one set of data available for customs officers, a different set for the terminal operators and so on. If the containers are fitted with RFID, handheld scanners or RFID portals could be used to access the relevant data for the organization in question.

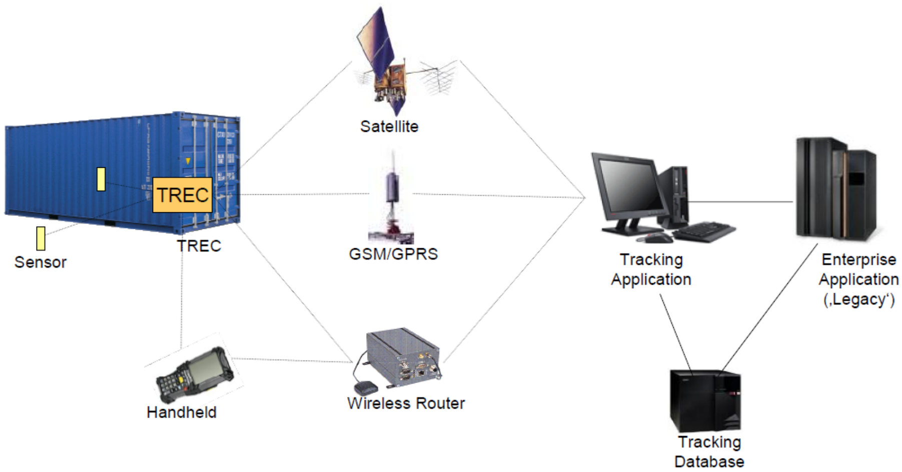

Figure 4.3: The architecture of the TREC secure trade line [16]

TREC can communicate through GSM/GPRS, the network used in cell phones, which has coverage in most populated areas. On the open sea or remote places (e.g. the Chinese hinterland) there is no reliable network coverage and TREC has to communicate through satellite. Short range communication can be established between TREC and the handheld scanner or between TREC and wireless routers, which could be installed in ports and distribution centers. This short range communication is done via the Zigbee protocol, which provides a low power consumption.

The Backend is the intermediary between the TREC and applications (e.g. route planning). It performs as the gateway for all GSM or GPS communication, it can be used to set business rules (e.g. maximum allowable temperature) and to send notifications if these rules are violated. The backend filters the received data from TREC and forwards this information to authorized parties through a portal.

Mahlknecht and Madani (2007) [17] propose a similar, yet different design which is presented in figure 4.4. Here each container is equipped with an Internal Monitor (IM), which consists of multiple sensors to gather data from within the container. Each container has a Container Monitor (CM) which gathers the data from the IM and sends it to the Prime Monitor (PM) directly or via other CMs. The PM has GSM, global connectivity (satellite) and global location awareness and is provided with an almost unlimited source of energy. There is only one PM per ship (or train). Using this design most of the energy consuming communication is done via the PM, allowing for a longer battery life and thus fewer maintenance required per container.

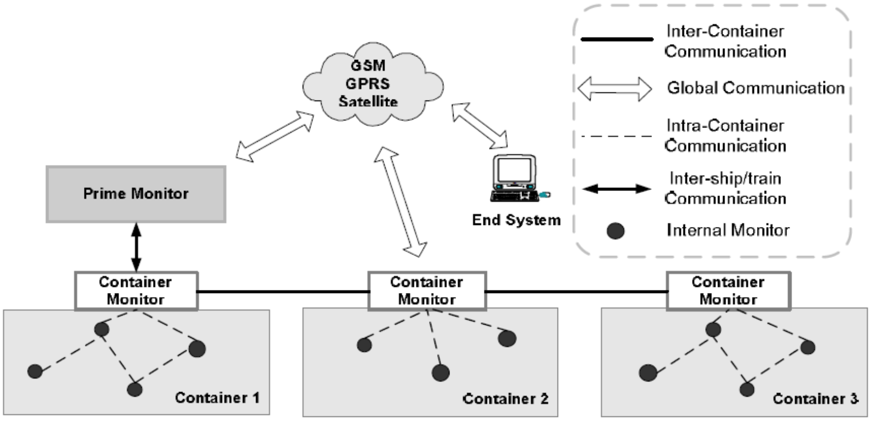

Figure 4.4: Communication system architecture proposed by Mahlknecht and Madani (2007) [17]

This solution could work very well in most occasions but Cimino et al. (2017) [69] argue that GPS is not an optimal way to determine container locations for terminal operators. This has to do with the limited accuracy GPS provides and even more so with GPS dead-zones, caused by huge quay cranes and other structures. One proposed solution is tracking the movement of the cranes, handling the containers, using GPS and store the information where each specific container has been put down. In this case the container would be equipped with an RFID tag and the crane with an RFID reader, so the identity of the container could be linked with the position where it was put down. This does not solve the accuracy and dead-zone problem however and provides no real-time location.

Abbate, Avvenuti, Corsini and Vecchio (2009) [18] propose a localization technique where every container is equipped with six wireless sensor nodes that detect the proximity of other sensor nodes attached to the neighbor containers (see figure 4.5). Each node has a unique NodeID and generates beacons, while listening to beacons generated by other nodes. The presence of nodes nearby is detected by analyzing the received signal strength (RSS) of these periodically emitted beacons. The RSS is not used to determine the distance between two nodes, but to determine whether another node is sufficiently close to be labeled as a peer node. Every node maintains a list of its peers and can have at most three peer nodes. Each node sends his peer-list to the base station through a multi-hop routing tree that is based on the shortest path algorithm, see figure

4.6. This peering information is analyzed and the relative and absolute positions of each container are determined from it.

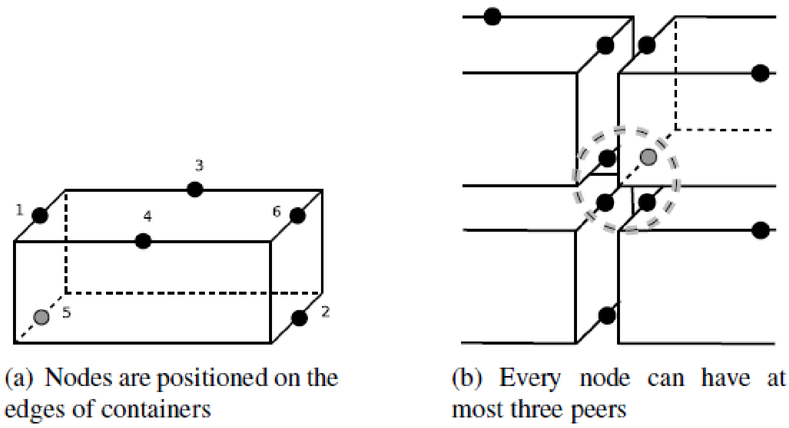

Figure 4.5: Container localization technique proposed by Abbate et al. (2009) [18]

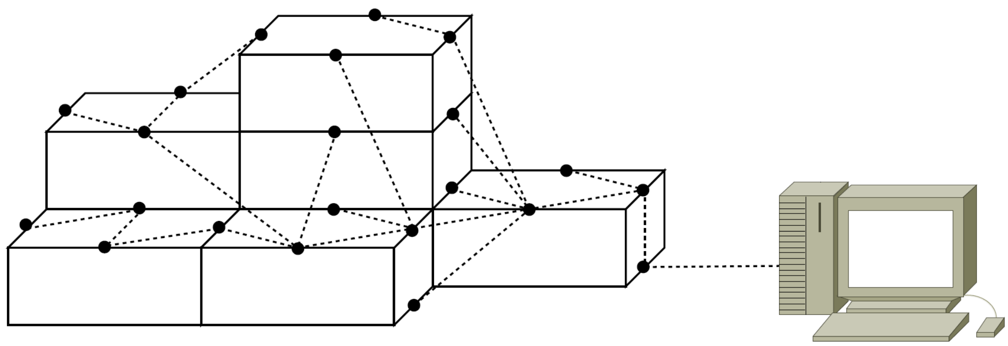

Figure 4.6: Routing tree from containers to the base station [18]

These advanced container tracking and monitoring architectures and designs would allow shipping lines to offer their customers a much more transparent supply chain. Via backend systems, applications can be developed that allow their customers to easily check where their goods are and what the status of their cargo is. The status and position of the smart containers could also be automatically uploaded to applications such as the TradeLens. This would allow all authorized members to easily track their goods and containers using the same platform. Container door sensors could prove very valuable for cargo theft prevention. Cargo theft is a billion dollar problem with Europol stating that over EUR 2.2 billion was lost in 2016 in Germany alone [70].

In addition to improved customer satisfaction and security, the supply chain operations have much to gain as well from this. The real time information on container location in the terminal results in more efficient terminal operations. This could give terminal operators room to charge the shipping lines lower prices and make sure their ships spend as little time as possible in the port, providing shipping lines with a direct incentive.

4.3 Condition-Based Maintenance

Maintenance includes all actions necessary to retain a system or an item in, or restore it to, a state in which it can perform its required functions. Coraddu et al. (2016) [71] recognize three forms of maintenance: corrective maintenance, preventive maintenance and condition-based maintenance. In corrective maintenance the equipment is used until it breaks down. After breakdown, maintenance is carried out to restore the system to the state it was in before. Corrective maintenance is a reactive approach because the action is triggered by an unscheduled event (i.e. the failing of equipment). The costs associated with corrective maintenance are high. Often one failed item damages another, the costs associated with the lost production can be huge and finally there are serious safety issues involved with the unexpected breakdown of equipment [72]. Corrective maintenance also may lead to a long unavailability of equipment, because of its reactive nature.

Preventive maintenance is carried out before breakdown occurs. This has certain advantages over corrective maintenance such as a higher level of safety and lower costs associated with lost production. Another non-trivial advantage is the fact that maintenance work can be easily planned ahead. Preventive maintenance is usually time-based which has the disadvantage that maintenance is carried out independently of the status of the equipment. In reality this comes down to a lot of unnecessary or premature maintenance. A research conducted by DNV GL [19] also raises the point that many failures are not age-related and would thus not necessarily be addressed by preventive maintenance.

Condition-based maintenance is carried out when it is necessitated by the condition or status of the equipment. By using a condition-based maintenance strategy, costs resulting from unnecessary maintenance can be reduced. Direct monitoring methods are used to determine the status of the equipment. For the application of condition-based maintenance the availability of measurement and data acquisition systems to monitor the status of equipment in real time are necessary [73]. These systems record and evaluate different measurable parameters such as vibration, acoustic, temperature, current signal, oil and lubricant measurements [74]. With the introduction of the Internet of Things more and more assets are equipped with sensors, and the ability to generate and communicate this data. On the basis of the equipment's condition, maintenance activities are scheduled to minimize costs and disruptions. Part of condition-based maintenance is not just determining the current condition of equipment, but predicting when the next breakdown will occur on the basis of the current status. For this purpose Big Data analytics and machine learning can be utilized. A representation of a data driven condition based maintenance framework is given in figure 4.7.

In the model depicted in figure 4.7 previous failure data is used as an input to train a machine learning model. The measured condition data is correlated with known failures using pattern recognition techniques. On the basis of this model a diagnosis is given on whether or not a component should be replaced or not. The prognostics extend the results of the diagnostics by estimating the future health state of the systems and predicting the remaining useful life. The prognostics algorithm is also trained by historical data in a machine learning fashion. The framework presented in figure 4.7 is in the case of a single component. When determining the health state of an overall system (e.g. an engine) there are many components, with many interrelationships, which determine the health state. In the framework presented in figure 4.8 the conditions of individual components are integrated at a system level and can be used to prioritize maintenance of certain components. A fault tree is composed of the system and used to determine the importance of components with respect to the overall health of the system. In combination with the the condition-based maintenance analysis of individual components this can be used to make an optimal maintenance schedule in terms of costs and safety.

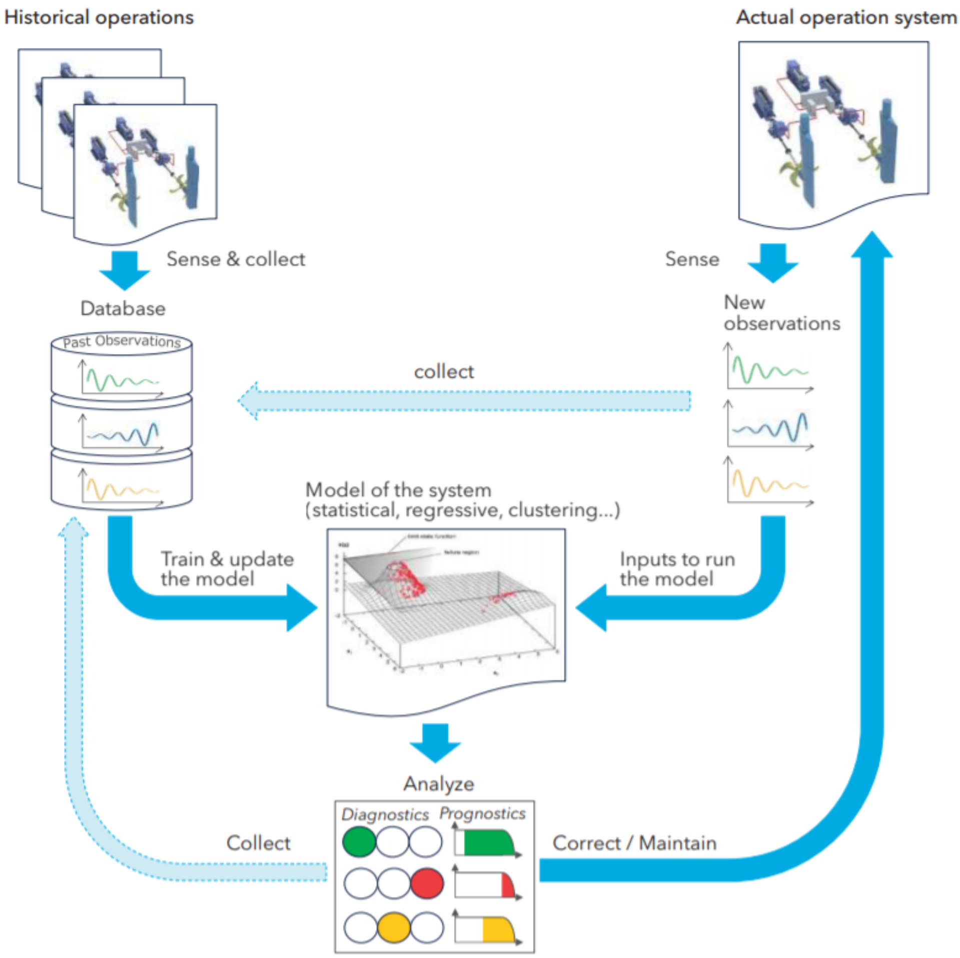

Figure 4.7: representation of a data driven condition based maintenance framework [19]

4.3.1 Vessels

For maritime applications maintenance is a very important task, aiming to reduce the costs of operations while getting the optimal availability of the ship. Repair and maintenance expenses for conventional ships amount up to 20% of total operating costs [75]. This would make it very interesting for shipping lines, port authorities and towage companies to apply condition-based maintenance to their ships. According to Lazakis, Raptodimos and Varelas (2018) [76] the maritime industry is still predominantly reliant on a time-based preventive approach to maintenance. For ships that do already apply a condition-based maintenance strategy the components that are most monitored are:

- The main engine
- The bearings and gears in the propulsion system
- The propellers
- The ship hull

The main engine is the component most often responsible for serious damages on ships [19]. This is one of the reasons that main engines have the the most sensors and the best monitoring systems. If the condition-based maintenance system indicates that a part is up for replacement, an order

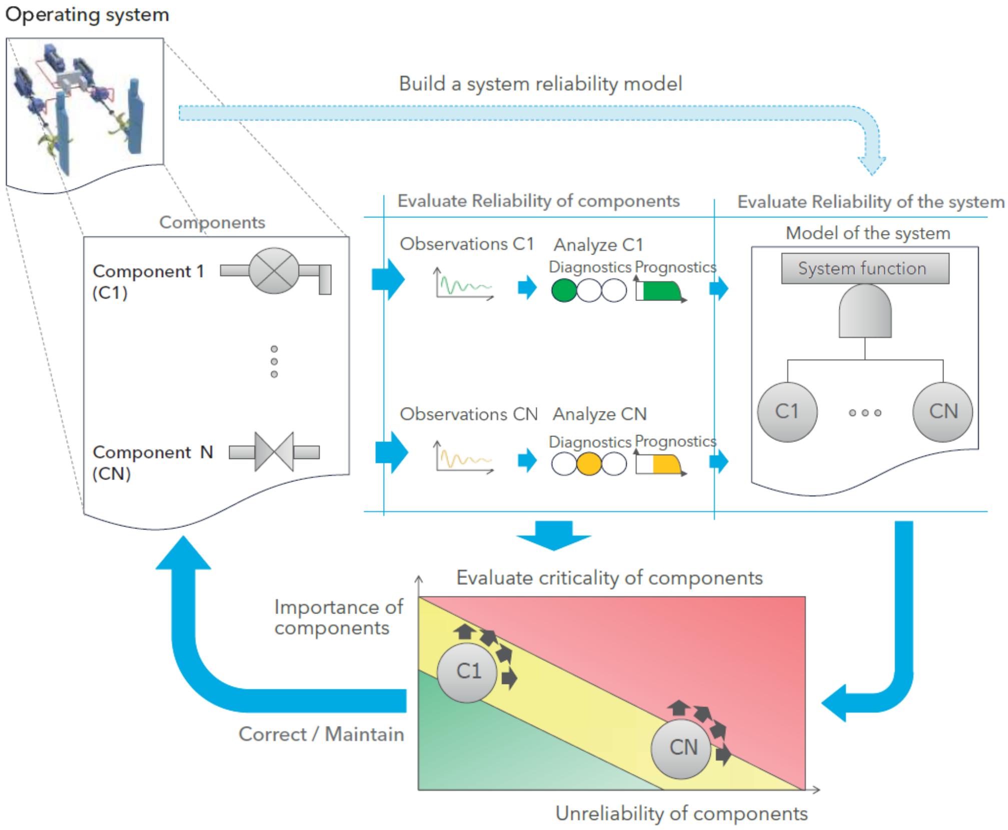

Figure 4.8: Representation of a data driven risk-based condition-based maintenance framework [19]

could be submitted automatically to a ship chandler in the nearest port. The ship chandler will in turn make sure that the part is there by the time the vessel arrives. If the maintenance system indicates that there is structural damage to the ship (e.g. hull stresses exceeding a certain threshold) an automatic notification could be sent to repair services in the port, allowing them to reserve personnel and a dry dock for when the ship arrives in port.

4.3.2 Container Cranes

Container cranes often are huge structures and when accidents happen, they tend to be very dangerous. The main structural failure type of container cranes is fatigue [77]. Crane health monitoring is an efficient way of determining the health state of container cranes. Li, Wang and Ding (2013) [20] propose a solution using wireless strain sensing nodes, communicating through a wireless Zigbee module, see figure 4.9. It is important that the sensing nodes are wireless, since the harsh conditions present in a container terminal render a wired network infeasible. The data acquisition gateway subsystem receives real-time measurement data from the sensing nodes, which connect with one another. It sends this aggregated data to the data processing subsystem via GPRS, which has a larger range than Zigbee. If it is unable to make a connection with the data processing subsystem it can locally store the received data and send it at a later time when connection has been regained.

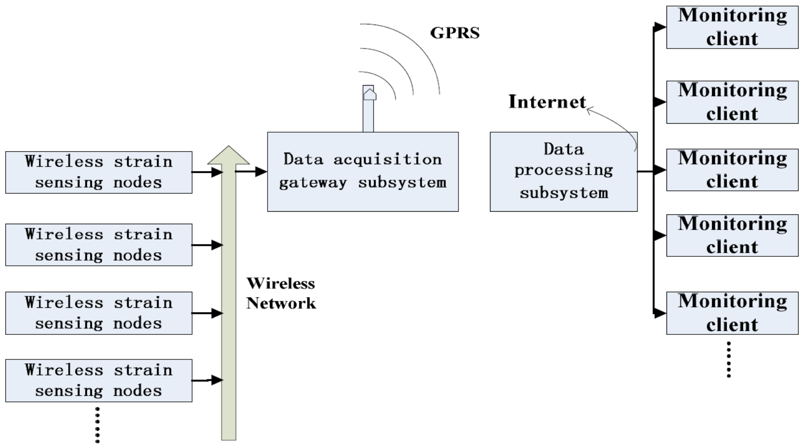

Figure 4.9: System design in structural health monitoring of cranes proposed by Li et al. (2013) [20]

The data processing subsystem is the center of the monitoring system. Its design is presented in figure 4.10. The data is preprocessed, stored and analyzed using crane health assessment software. The software can send out early warnings of structure damage, assess the overall safety of the crane, predict the remaining lifetime and propose maintenance strategies.

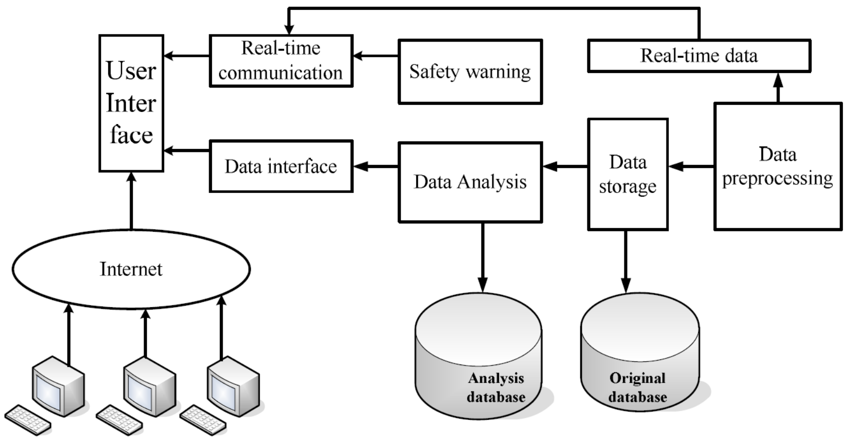

Figure 4.10: Data processing subsystem [20]

4.4 Automation Of Terminal Operations

In the port community the greatest level of automation has been achieved by the container terminals. Martn-Sobern, Monfort, Sapia, Monterde and Calduch (2014) [21] recognize the following features of container terminals which have allowed them to reach a relatively high level of automation:

- The standardization of the means of transport-containers
- The standardization of the manner in which freight is handled
- The high level of interchanges taking place
- The high impact of technology on the profitability of terminals

In short, terminal operations consist of the high number of repetitive movements of standardized cargo (i.e. containers). Add to this inter-terminal competition and a drive for automation is the logical consequence.

The main advantages and disadvantages of automating container terminals are presented in figure 4.11. The (dis)advantages have been subdivided into the economic and financial probability, and into the three strategic needs that modern terminals require according to Martn-Sobern et al. [21], which are:

1. Improving the operational performance
2. Increasing safety and security in the terminal
3. Improve on the contribution to environmental sustainability

The improvement in operational performance might be the biggest incentive for terminals to automate. Automated terminals are more productive, make better use of the available space, meaning they can sustain a higher yard density and offer more capacity, and make more efficient use of their resources (e.g. minimizing the number of container shuffles a yard crane has to perform). Since operations are more organized, the uncertainty in response times goes down. An automated terminal faces much less exposure to external factors such as labor strikes (which are not uncommon in e.g. France [78]) or crane operator sickness. A disadvantage in the section of operational performance are the potential problems that exceptional occasions could create, since automated equipment would not be able to deal with certain situations. A possible solution for this could be to allow the possibility of remote controlling equipment by an operator in special occasions.

The Safety in the terminal is increased by eliminating human error in operations and by creating a physical gap between people and the container handling areas. This means that if an accident is to occur, it is less likely to result in human injury. An increase in security can be reached by automating the gate operations, this is presented in section 4.4.3.

The more efficient use of resources leads to minimized travel from equipment, prompting a decrease in energy use. Automated terminals often use electrically powered equipment, which lead to reduced emissions since the energy comes from cleaner solutions or power plants that operate more efficient than combustion engines. A disadvantage belonging to the sustainability section is the net loss of jobs which accompanies terminal automation.

Finally from a financial point of view, the maintenance operational costs go down due to elimination of human error in handling equipment. The disadvantage of high implementation costs, should be made up for in the reduction in the variable cost per container.

The automation of container terminals takes place in three areas:

1. Automation of the tasks
2. Automation of information flows
3. Automation of the decision making process

The automation of the tasks being carried out comes down to making the infrastructure and the equipment (more) autonomous. The automation of information flows is concerned with the automatic acquisition, transmission and management of information. The automation of the decision making process removes the human factor in the decision making. The assignment of certain quay cranes to handle a certain vessel is an example of the decision making. For the automation of the tasks automated equipment (e.g. automatic cranes, automated guided vehicles) is needed. For the automation of information flows and decision making a terminal operating system (TOS) is required. In the following sections the automated terminal equipment, the TOS and the gate operations will be discussed.

	Advantages	Disadvantages
Operational performance	• Increased operational productivity • Operating with allocations and high yard density: offering more capacity with the same space • Increased flexibility to adapt to demand peaks • More organised and methodical operations, reducing uncertainty in response times • Higher capacity to prioritise operational changes • Less affected by external factors and lack of stevedores • More efficient use of resources • More control of operations given the existence of continuous communication between control systems and the fleet of equipment, easing thereby the decision making process in real time • Less volume of shuffling operations required which can be planned in advance to be carried out without interfering with loading and unloading operations (housekeeping)	• Less flexibility for operational planning • New scenarios have to be previously planned • More difficulty to react when exceptions occur
Safety and security	• Increase in safety in PCTs given the reduction of risks to human resources • Incorporation of security systems	
Environmental sustainability	• Operating with electric equipment (less consumption, less emissions and less noise) • Best use of current spaces (fewer extensions)	• May generate labour conflicts (loss of job positions)
Economic and financial profitability	• Less variable operational costs • Less maintenance operational costs	• Require a (higher) capital outlay

Figure 4.11: Advantages and disadvantages of automated container terminals [21]

4.4.1 The Automation Of Container Handling Equipment

The container handling equipment inside a container terminal can be subdivided into three categories:

1. quay cranes
2. yard cranes
3. horizontal transport equipment

Quay Cranes

The type of equipment used differs among container terminals all over the world. However, the main equipment that is always present is the quay crane, which loads and unloads the vessel [79]. When unloading a vessel, a quay crane lowers its spreader towards the container, in order to lift it up. The trolley moves in the direction of the quay and the container is transferred to the terminal's horizontal transport equipment. In order to start a new cycle, the spreader will move towards the vessel again. Quay cranes can become the limiting component in terminal productivity [22]. So in order to increase the productivity of the quay cranes automation seems obvious. However, automation of quay cranes is in a less developed state, compared to other container handling equipment, because of the challenges the environment poses. These challenges include unpredicted vessel movements and wind influence on the spreader and container [24]. A classification of quay cranes by their degree of automation is given in figure 4.12. Currently modern container terminals mostly use semi-automated quay cranes, where the operator remotely controls the crane and is assisted with anti-sway systems, automatic positioning systems and smart spreaders [22]. An anti-sway system uses a computer which reads the operator's commands from his control stick and modifies this command to the motor drive to control sway. The automatic positioning system uses cameras on the spreader, which are processed to locate the twist locks on the container. On the basis of this information, a control signal is sent to the crane operator with information on how to move and complete the alignment. The smart spreader automatically twists the twist locks 90 degrees when it senses the spreader is in the right position.

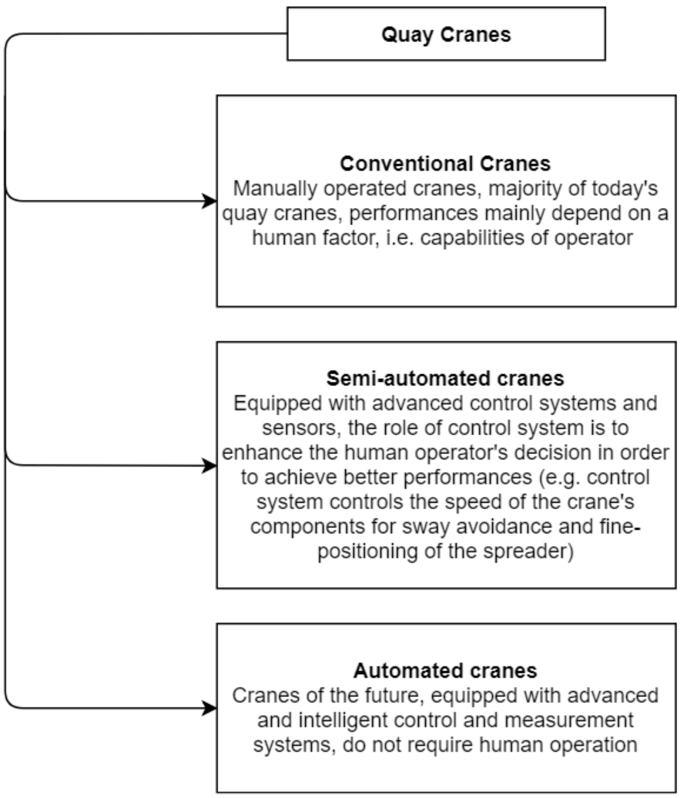

Figure 4.12: Classification of quay cranes by their degree of automation [22]

Yard Cranes

Yard cranes are used to put containers in the stack, get containers out of the stack and reshuffle containers within the stack. The two most common yard cranes are the rail mounted gantry crane (RMG) and the rubber tired gantry crane (RTG), because of their high storage capacity in containers per squared meter [80]. The RMG is utilized both as a yard crane and as an intermodal crane, servicing trains. RMGs can already be automated, since the trucks and trains it services are stationary with respect to the RMG [24]. To automate an RMG three positions must be known at all times: the position of the crane gantry, the position of the trolley and the position of the spreader. To meet these conditions sophisticated sensors are deployed on the crane and its surroundings, see figure 4.13.

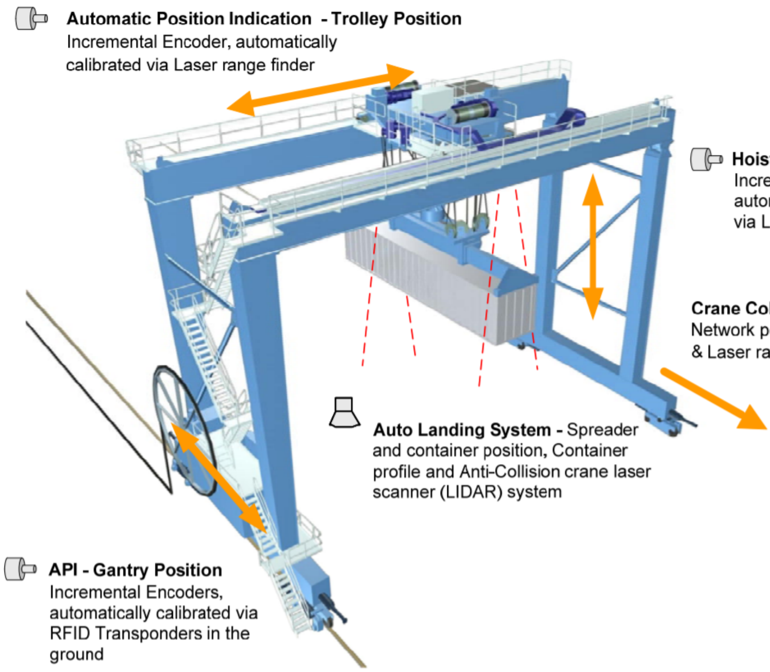

Figure 4.13: Rail Mounted Gantry Crane for Automatic Container Stacking [23]

The gantry position of the RMG is being monitored by RFID sensors that are located in the ground alongside the track and RFID readers, which are deployed on the crane itself. The position of the trolley is monitored using a laser sensor. For determining the relative position of the spreader with respect to the container an auto-landing system can be used, which uses optical laser systems to measure the distance and angle to the container. Furthermore, a crane collision avoidance system is implemented using laser sensors, since often more than one RMG operates the same stack.

RTGs are operated and automated quite similar to RMGs. RTGs are equipped with rubber tired wheels, instead of being mounted on a rail. This allows for more flexibility in the terminal, since RTGs are able to switch lanes across the stack. The RMGs on the other hand have a slightly higher storage capacity [80].

Horizontal Transport Equipment

Horizontal transport equipment refers to the equipment that transports containers between the quay and the yard, and between the yard and the truck/train area [1]. The most common automated horizontal transport equipment is the AGV.

AGVs use electric motors, which are powered by a battery or a diesel-driven generator [24]. The electronics system of the AGV consists of controllers, sensors, actuators, communication systems and the wiring linking the components. In order to successfully automate AGVs the location should be known at all times. The AGV controller uses the location and velocity of the AGV to

[1] Some terminals do not have a designated truck area, but load/unload trucks at the end of the stack, using yard cranes.

determine the required direction and velocity [24]. There are multiple ways how the location of AGVs can be determined. Based on Duinkerken (2018) [81] the four most relevant localization techniques will be discussed, namely: line, wire, grid and GPS.

The line, or guide tape, method uses tape for a guide path. The AGV uses appropriate sensors to follow the path of the tape. Since the position of the tape is known, the location of the AGV can be derived. The wire method uses buried wires, which transmit a radio signal. Sensors on the AGV are able to determine the distance of the AGV relative to the wire. Since the location of the wire is know to the AGV, its position can be calculated. Both the wire- and the line method are very popular in container terminals because of their relative ease. A downside is the fact that the AGV has to follow the wire or tape and thus it lacks flexibility. The grid method can use RFID tags to create a grid on the terminal floor. Each AGV has RFID readers which receive signals from nearby RFID tags. Depending on which RFID tags' signals are received, its position can be derived from this. The fourth method is through GPS, where a GPS sensor on the AGV can determine its position. The advantage of the grid- and GPS method is the possibility of free-ranging, meaning that the AGV does not necessarily need to follow a prescribed path. A disadvantage of the GPS method is the possibility of dead-zones in the container terminal (as was presented in section 4.2).

The AGV receives information about its destination and compares this to its current position. The outcome of the comparison determines the velocity and direction of the AGV. The system and control cycle for the controller is presented in figure 4.14. The position, velocity and heading are the measured states of the AGV and the actions are changing the steering angle and applying a torque to the wheels.

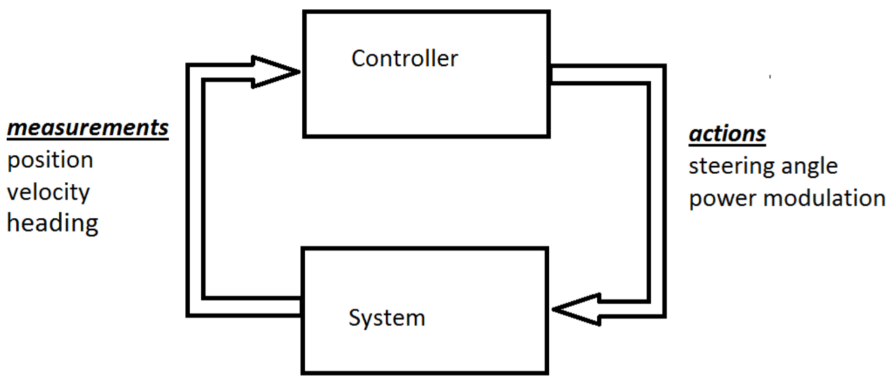

Figure 4.14: AGV's system and control cycle [24]

In order for the automated equipment to perform all the container handling tasks in an efficient way, a terminal operating system is required. It is necessary that the data sensed by the equipment is communicated to this system. This is done in an Internet of Things fashion, as presented in figure 4.15. Communication techniques (e.g. 4G) are used to communicate data to the terminal operating system, where the received data can lead to new insights and better control of the entire container handling process.

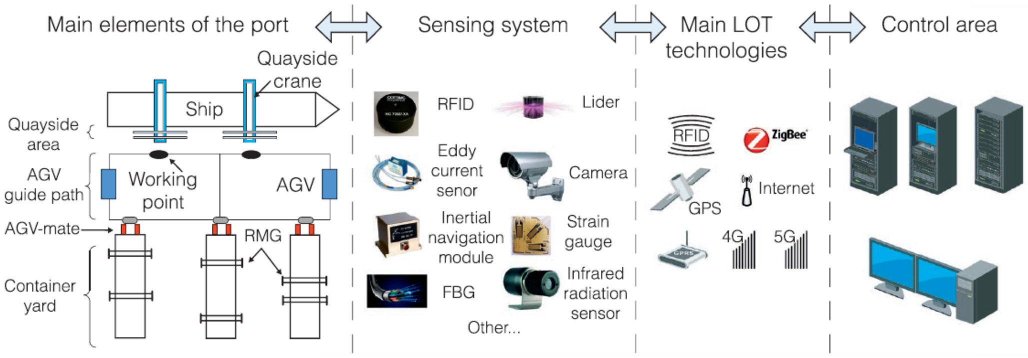

Figure 4.15: Internet of things methodology in a container terminal [25]

4.4.2 Terminal Operating Systems

Operations in automated container terminals must be supported by a terminal operating system (TOS), which is used to make required decisions for daily operations in real-time fashion, while considering the current situations in the container terminal [27]. Kim and Lee (2015) [26] summarize the required control activities in the container terminal in figure 4.16. It can be noted that in a completely auomated terminal the function of *operator management* will be no longer necessary.

Classification	Functions	Decisions to be made
Ship operation	Berth monitoring	Problem detection, alerting & solving
	Load & discharge control	Operation scheduling
	QC operation control	Equipment scheduling
	Transporter control	
Hinterland operation	Transport monitoring	Problem detection, alerting & solving
	Gate management	
	Barge management	
	Rail operation management	
Yard operation	Yard monitoring	Problem detection, alerting & solving
	Yard positioning	Real-time container positioning
	House-keeping	Re-marshaling & shuffling
	Reefer operation control	YC scheduling
	YC control	
Resource control	Equipment management	Workforce & equipment deployment
	Operator management	

Figure 4.16: Required control activities for managing a container terminal [26]

How a TOS in a container terminal exactly goes about realizing these tasks in the industry is not publicly shared for obvious reasons. In the past, a centralized structure was most popular for a control system because of its simplicity in conceptual design. When material handling systems that consist of a large number of automated facilities are considered, it is recognized that these complex systems are beyond the control of centralized direction and a more distributed approach must be taken. Singgih, Jin, Hong and Kim (2016) [27] propose a distributed solution, which is presented in figures 4.17 and 4.18.

The Planning System handles the berth allocation for ships and the load sequencing list, as delivered by the shipping line, and communicates this to the Process Manager of the TOS. These tasks can be scheduled without too many necessary alterations, since they do not change so much. The remaining terminal operations are very difficult to plan well in advance, because of the high level of uncertainty that accompanies them. These operations are handled by the TOS in real-time fashion, meaning operations are not planned far into the future and they are constantly updated. The TOS consists of a Process Manager, a Quay Crane (QC) Manager, a Transport Ground (TG) Manager, a Transport Yard (TY) Manager, a Hinterland Manager, a Yard Manager, automated equipment and a database.

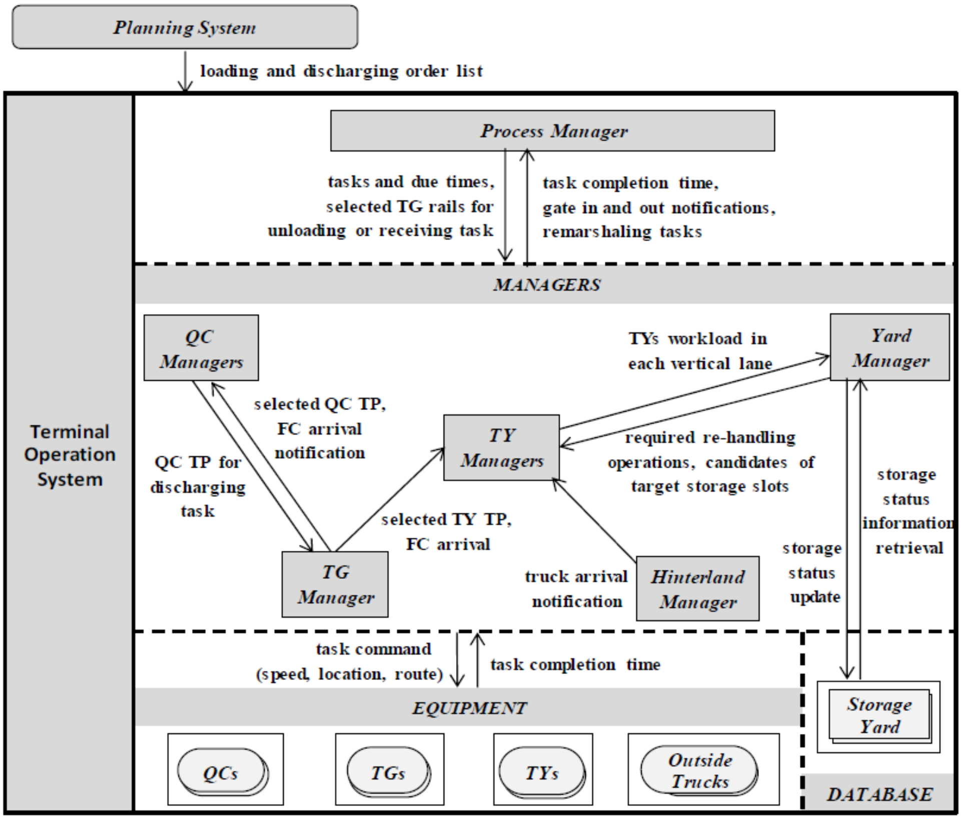

Figure 4.17: TOS architecture presented by Singgih et al. (2016) [27]

The QC Manager receives the tasks based on the load sequencing list and divides the loading and unloading tasks amongst the QCs.

The TG manager is in charge of dividing tasks amongst the TGs, routing them and preventing deadlock situations.

The TY Manager determines and communicates the required task to the automated yard cranes. It schedules these tasks and keeps monitoring whether the schedule is feasible (e.g. when two yard cranes operate the same stack, their schedules should not conflict and lead to potential collisions). Furthermore the TY Manager solves possible deadlock situations and selects the specific storage location for containers. When yard cranes are idle, they start remarshaling containers. A remarshaling order is used to relocate a container in the yard in order to speed up future processes.

Manager	Function
Process Manager	Loading, discharging, receiving, remarshaling, and delivery tasks generation and due time determination
	Rescheduling related task because of a task delay
QC Manager	Next QC (loading/unloading) task selection
	QC TP selection (for QC movement)
TG Manager	TG dispatching
	TG TP determination
	TG network design (determination of path segments' directions)
	TG (empty and loaded) routing
	Idle TGs parking location determination
	Cyclic deadlock prevention among TGs by allocated task exchange or TG rerouting
	Deadlock resolution among different types of equipment
TY Manager	Next TY task selection
	TY scheduling, including collision avoidance (using a single TY)
	TY relay operation scheduling (using two TYs on the same rail)
	Deadlock resolution caused by mismatch between TG and TY (allocating task exchange to TYs)
	TY re-handling task generation and due time determination
	Specific storage location determination
Yard Manager	Candidate of specific storage location determination for discharging, receiving, and remarshaling containers
	Storage bay determination for receiving, discharging, and remarshaling
	Remaining duration of stay checking for containers to be remarshaled
Hinterland Operation Manager	Yard congestion checking
	TP determination
	Truck routing

Figure 4.18: TOS manager functions presented by Singgih et al. (2016) [27]

The Yard Manager plays a role in selecting container storage locations as well. When a new container enters the terminal the Yard Manager requests information about the workload of the yard cranes from the TY Manager. On the basis of this information the yard manager determines in which stack the container will be stored and sends a number of storage slot candidates to the TY Manager. The TY manager picks one of these slots, which does not cause possible schedule or collision conflicts and sends the order to a yard crane.

The Hinterland Manager sends a notification when a truck arrives in the terminal. After the storage slot has been chosen the Hinterland Manager helps in routing the truck to the designated transfer point (TP).

The tasks that are to be executed by each manager are generated by the Process Manager. An order is performed using multiple pieces of equipment (e.g. the exporting of a container requires operations from trucks, yard cranes, TGs and QCs), which are all being directed by their respective managers. If each manager only aims to optimize their own equipment operations, ignoring the schedules of other equipment, long waiting times and delays will occur. To avoid this situation the Process Manager performs the integrated scheduling function. The integrated scheduling function calculates the due times of each task performed by each piece of equipment, which is needed to complete the task (e.g. when receiving a container from a vessel, the due times of the unloading of the QC, the arrival of the TG at the yard TP and the storing of the container in the yard by the TY are calculated). This calculation is done by considering the estimated operational time required of the equipment. These calculated due times are used as the basis for the scheduling by each manager. This allows the schedules of all the equipment to be synchronized. If the completion of a task is delayed (due to unpredicted traffic, breakdown of equipment etc.) it is recorded by the equipment manager and communicated to the Process Manager. The Process Manager then updates the calculated due times and informs the equipment managers, who in turn then may reschedule tasks.

A few things could be added to the TOS presented by Singgih et al. (2016) [27]. In the first place a gate system can be added to the TOS. How this may work in practice is elaborated upon in section 4.4.3. In the second place an Information Manager could be added. The Information Manager could keep track of all the documentary requirements for each individual container and the status of them in this regard. If a vessel arrives and the documentation for a certain container is not in order the Information Manager should communicate this to the Process Manager. The Process Manager then should not create the task of loading this container onto the vessel. The Information Manager could also retrieve information about the documentary status of containers from an application such as TradeLens, as presented in section 4.1. This would include all the advantages named in section 4.1 and goes to show that a TOS and global supply chain on the blockchain could supplement each other.

4.4.3 Gate Operations

When a truck driver plans on picking up or dropping off a container at a container terminal, he must pre-announce his visit and details should be registered such as: container number, driver name, vehicle and truck number, weight of goods, contents and often also an e-seal number [82]. During the picking up or dropping off of the container, the truck driver usually passes multiple gates. At these gates many things are checked such as: the identity of the truck driver, the license plate of the truck, the container number, possible damages to the container and the presence of a seal on the container. In most ports in the world at least some of these steps are still carried out using manual operations. Automating this process has multiple advantages, such as:

1. Reducing queues at the gate-in and improve terminal efficiency due to faster operations
2. Real-time updates of container information into the system
3. Take away the human error and thus improve efficiency and security of terminal operations

Lee, Huang, Gong and Wang (2011) [28] have designed the so called Non-Stop Automated Escort and Gate (NSAEG) system which is able to automate the above mentioned requirements. The conceptual framework of the NSAEG system includes five layers as show in figure 4.19. The first layer is the data-capturing front-end. Here RFID readers are positioned at the gate to read and verify the e-seal ID number. The drivers identity (CDC number) is automatically checked using an on-board unit, which is present in most trucks. Finally the license plate number and the container number are automatically checked using optimal character recognition (OCR) devices, which mainly consist of cameras and lighting. The OCR can be used for additional functions such as image storage for possible container damages. All the sensors are connected to the same network and send their data to the second layer. The Data Capturing Layer filters, aggregates and transfers the data in real-time. In the third layer the captured data is verified and stored in databases. The Gate Control Layer checks whether the recorded data is in accordance with the registered details given before the arrival. If all the information is in accordance with the perceived data the container is allowed to move on.

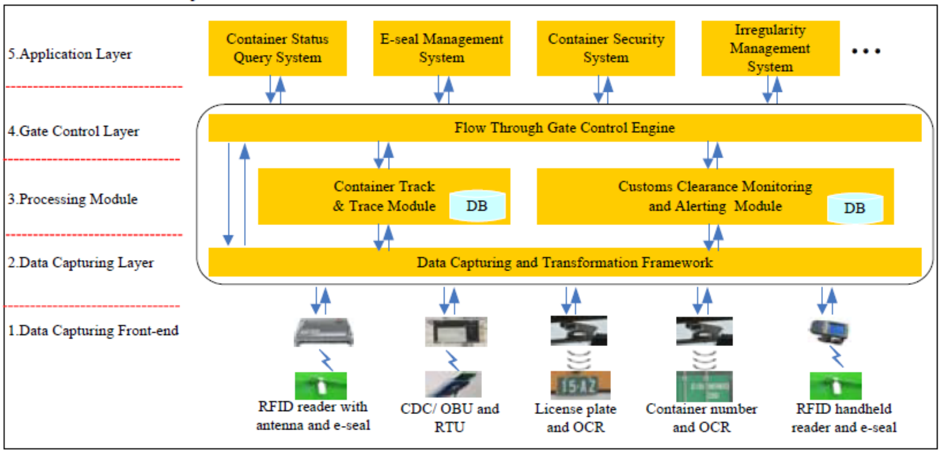

Figure 4.19: Non-Stop Automated Escort and Gate system proposed by Lee et al. (2011) [28]

4.5 Smart Customs Control

Enormous volumes of cargo flow through ports and these volumes are only expected to grow in the future. Customs are responsible for collecting tariffs on- and controlling this flow of goods, which becomes increasingly challenging every year. Chalfin (2007) [45] reports that during the first months of the year 2006, only approximately 2% of import declarations in the Netherlands as a whole were subject to physical controls. In order to keep up with this increasingly challenging task, operations have to be conducted intelligently using a Customs Risk Management System (CRMS). The design for the CRMS as used by the Dutch customs is presented in figure 4.20 [29].

The Entry Summary Declaration (ENS) is a European obligation and part of the Import Control System (ICS). For all cargo vessels outside the EU, a declaration of all goods on board originating from outside the EU must be submitted to customs at least four hours before arrival, which can be done using one of the Import Cargo Services (see section 2.10) of Portbase [46]. Imported goods must be reported with a Single Administrative Document (SAD) declaration also according to EU regulations. On the basis of these declarations a risk engine, using a declaration information processing system called PRISMA and a business rule engine called BLAZE, assesses the risk of each declaration and decide if the container should be inspected (red flag), should not be inspected (green flag) or whether further supervision is needed (amber flag). For the amber flags the management dashboard CRIS (Customs Real time Information System) collects external information and acts as a decision support system. CRIS is to be the access of customs to the data pipeline of a certain container [83].

The Dutch Customs Administration (DCA) has been working on a machine learning system which could be implemented on CRIS to keep improving the risk analysis of amber flagged goods. The machine learning algorithm used is a random forest, because of its good performance when finding non-linear correlations [29]. The scheme of the machine learning project is given in figure 4.21, where the grey area within the "all data" represents the customs declarations, with the label of the inspections results attached to them, already cleaned and pre-processed. Of this selected data 75% is used to train the model and 25% is used to test it. The result of the machine learning model is a number between 0 and 1 according to the relevance of the risk, which is presented to the customs officer. The decision on whether or not to ultimately inspect still has has to be made by the customs officer.

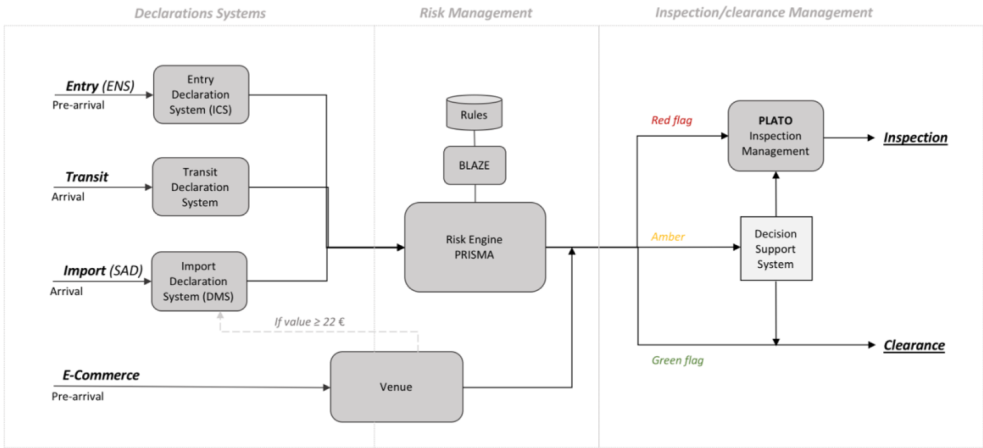

Figure 4.20: Customs risk management system [29]

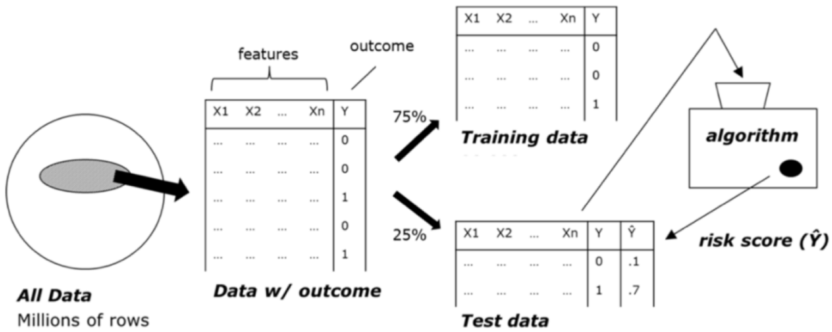

Figure 4.21: Scheme of the machine learning project used at Dutch Customs Authorities [29]

The packages that have been classified as the ones to be inspected are then processed by the system PLATO. This system is in charge of assisting the DCA officers during the inspections, for instance recording the results of the inspections [29]. In the case a container is selected for inspection by the system, this is initially carried out via remote scanning. Each container terminal on the Maasvlakte has its own on-site scans, the images are then sent to- and analyzed at the State Inspection Terminal (SIT). In some cases it is decided that physical inspection is required and the container is transported to the SIT. As smart containers (as discussed in section 4.2) make their entry certain sensor data could also be shared with customs. In the case of an intrusion detection, this should be reported so that customs can pick out the container in question and schedule it for immediate physical inspection.

4.6 Summary On The Applications Of Logistics 4.0 In The Port Community

In this chapter the key question: "*Which applications of logistics 4.0 are possible in the port community and how do they work?*" has been answered. Firstly, the moving of the global supply chain to the blockchain has been presented. This application would make the global supply chain (of which the port community is an indispensable part) much more efficient and secure. Communications would become faster and easier, allowing for a more efficient process. Furthermore, the blockchain would create a single source of truth in case a dispute would arise and finally it would become impossible to forge documents or tamper with them, eliminating huge costs associated with fraud. A blockchain application from the industry, named TradeLens, has been presented comprehensively. Multiple system architectures for smart Containers have been presented, which could send data regarding their position and status all over the world. The introduction of a global supply chain underpinned by blockchain technology, and the smart container ensures a tremendous increase in supply chain visibility and reliability. The enormous amount of data generated by system components can be processed and stored in Big Data fashion, to be used subsequently to train machine learning models. These models can be used to implement a condition-based maintenance strategy, which has a considerable cost-advantage over preventive maintenance. The main applications of condition-based maintenance in the port community are vessels and cranes. The automation of operations in container terminals improve the operational performance, increase the safety and security in the terminal and contribute to environmental sustainability. The automation of container terminals required both automated equipment and an intelligent way of controlling them. To deal with the control aspect, container terminals employ terminal operating systems. Finally, customs could use a machine learning algorithm to assess the risk of the enormous volume of cargo that flows through the port every day. Utilizing this machine learning algorithm not only improves the current risk-management system, but lowers the workload of customs officers. Customs officers could spend more time physically inspecting containers, since the time needed for risk assessment would decrease.

Chapter 5

Challenges

In chapter 2 the port community was presented, as were in chapter 3 and chapter 4 respectively the concept of logistics 4.0 and the applications of logistics 4.0 on the port community. In this chapter the biggest challenges to applying logistics 4.0 activities in the port community will be presented, as its adoption is not so straightforward.

5.1 Mutual Trust And Data Sharing

Especially when applying inter-organizational logistic 4.0 initiatives a certain level of mutual trust between participants is required. The shipping industry is very competitive, leading to an accompanying level of distrust between shipping lines. The TradeLens initiative (section 4.1) was launched in a collaborated effort of IBM and Maersk Line. So far the shipping lines that have joined (or indicated that they would join) TradeLens are: Maersk Line, Hamburg Süd, Pacific International Lines and Boluda Lines. These four lines carry a combined market share of 20.8% [84]. In order for an initiative such as TradeLens to be truly successful a larger adoption across industry players is necessary. Other major shipping lines such as Cosco, MSC and CMA CGM are not yet eager to join TradeLens, as they do not feel comfortable about Maersk's involvement in and partial ownership of the project. In fact according to a press release [85], shipping lines CMA CGM, Cosco, Evergreen Marine, OOCL, Yang Ming and others are planning to develop a blockchain platform called the Global Shipping Business Network (GSBN). The GSBN would essentially have the same functions as TradeLens. This lack of trust between shipping lines could lead to multiple platforms for global trade, meaning that all members of the port community (excluding the shipping lines) would need to operate these multiple platforms, which does not seem optimal.

Data sharing follows the line of mutual trust and takes it one step further. Data sharing could have many advantages, especially in the area of condition-based maintenance. As presented in section 4.3, condition-based maintenance models use data from past observations to train the model. For example, in the airline industry this works quite well, since aircrafts are produced in series of thousands and mostly use the same equipment. Large vessels are more unique and usually produced in series of 2-10. So failures and measurement data accumulate much more rapidly in the airline industry and condition-based maintenance models have very much data at their disposal. In the shipping industry these large databases for model training purposes are much harder to obtain [19]. Even though vessels are more unique, they use many identical components. The building of comprehensive databases should be possible if measurement data could be shared between different organizations. Of course it remains the question, whether shipping lines are willing to make these kinds of agreements with one another.

5.2 Cyber Security

Security is a major issue for port terminals, shipping lines and other members of the port community. When implementing logistics 4.0 applications, control and information systems become an indispensable part of the process. However the possibility to connect to and control physical systems through cyberspace increases their vulnerability to intentional attacks [86]. Beaumont (2017) [30] recognizes five threat actors against container terminals, their characteristics and a suggested motivation for their cyber-attacks.

Threat actor	**Characteristics**	**Suggested motivation for conducting cyber-attacks against container terminals**
Criminals	Modest technical abilities, predominantly motivated by financial gain.	Criminals could profit by manipulating electronic records to facilitate smuggling or to extort payments from port operators through the use of ransomware.
States	High levels of technical ability, motivated by intelligence gathering, military advantage.	Rival states could benefit by using cyber-means to disrupt CT operations at military ports during times of war. They may also benefit by collecting commercially sensitive information which may provide an advantage to their own industrial base.
Terrorists	Low to modest technical abilities (yet increasing).	Terrorists could disrupt the supply chains of important products such as foodstuffs in order to disturb normal pattern of life and to make political statements.
Hacktivists	High levels of technical ability (often crowd sourced). May provide their services to terrorists and state-actors if their aims align.	Hactivists could disrupt the supply chains of important products such as foodstuffs in order to disturb normal pattern of life and to make political statements.
Insiders	High levels of access to systems and physical infrastructure. May act independently or provide assistance to other categories of threat-actor.	To cause damage to a company in response to a personal grievance or to work for financial gain on behalf of one of the other threat actor categories.

Figure 5.1: Classification of different threat actors, their characteristics and their motives [30]

The first threat actor is the criminal who is motivated by financial gain. Manipulating electronic records would actually become extremely hard for the criminal when the global supply chain would be moved on the blockchain, as suggested in section 4.1. Another cyber attack by criminals is hacking computers with ransomware. This has been proven to be very dangerous. In June 2017 the APM terminal in Rotterdam was the victim of such an attack, resulting in unemployed cranes that were unable to unload vessels for multiple weeks [87]. A second threat actor are rival states, motivated by gathering intelligence and stealing intellectual property. For example, the Chinese government has been accused on multiple occasions of corporate cyber-espionage by American companies such as Google [88]. Other potential threat actors include terrorists, hacktivists and insiders.

For organizations to guard themselves against these dangers an organizational culture and awareness on cyber security is vital. Organizations should have the right protection mechanisms in place in case of a potential attack. The International Maritime Organization has named the following five functional elements in cyberrisk management [89]:

1. Identify

2. Protect

3. Detect
4. Respond
5. Recover

Identify is concerned with defining personnel roles and responsibilities for cyber risk management. It is also concerned with identifying systems, assets and data that can pose risks to operations, when disturbed. Protect is concerned with implementing risk control processes to protect against cyberattacks. Detect is charged with developing and implementing the necessary activities to detect cyberattacks in time. Respond refers to activities to provide resilience and aims to implement plans to restore systems in order to continue operations that were harmed by cyberattacks. Finally recover is concerned with constructing measures to back-up and restore all cybersystems for operations.

Big Data still faces some security challenges as well. The same tools and techniques that are being used to provide security for a regular database will no longer be sufficient in a Big Data environment [90]. Salleh and Janczewski (2016) [91] indicate that the sheer volume of the data will outrun the capacity of standard security products. They name one of the challenges to be providing security technologies that can scale to the large size of the data sets. The speed at which the data is generated and the variety of the data amplify the complications [91]. Organizations are familiar with security mechanisms for structured data (e.g. sensor measurements), but the protection mechanisms of unstructured data (e.g. camera images, videos) is still in its growing phase.

5.3 Social Challenges

In the logistics 4.0 applications proposed in chapter 4 two of the main themes are increasing efficiency and automation. TradeLens, as presented in section 4.1, allows shippers to track and monitor their goods themselves online, thus reducing the need for customer service personnel for shipping lines. The introduction of condition-based maintenance, as presented in section 4.3, results both in fewer maintenance activities than with preventive maintenance and in the automation of building maintenance schedules. Both results contribute to a reduced need for maintenance staff. The automation of terminal equipment and its control, as presented in section 4.4, results in a decreased need for terminal personnel. The introduction of a machine learning project in the risk assessment of containers performed by customs, as presented in section 4.5, reduces the required number of customs agents since their operations have become much more efficient. The dismissal of employees can be viewed from an ethical and a financial viewpoint.

Acemoglu and Robinson indicate in their award-winning book Why Nations Fail (2012) [92], that radical technological disruptions are accompanied by 'creative destruction', which among other things means that existing skills and jobs become obsolete due to the new technologies. They argue that even though these social challenges will arise, the introduction of new technologies must go through, as it is the engine of process. Other studies show that new technologies do not necessarily result in a net loss of jobs, as it allows for the creation of new jobs. It is in the line of expectation that the demand for information technology specialists will increase, as the demand for machine operators decreases. A McKinsey study in 2011 found that the internet had replaced 500,000 jobs in France in 15 years time. However, during the same time it had created 1.2 million new jobs [93]. One third of the jobs created in the United States in the 25 years previous to 2017, did not exist before [93]. On the basis of these arguments the dismissal of employees from an ethical perspective could be justified.

From a financial perspective other problems arise for companies that wish to automate. A first step should be to assess whether employees can be retrained for a different position within the same organization. If this is not possible the employee can be fired on the grounds of dismissal for economic reasons [1]. This is however an uneasy and expensive process for the employer as a transition fee has to be paid to the employee that can add up to 80,000 Euros in The Netherlands per employee, depending on his/her age and the duration of his/her employment [94].

5.4 Summary On The Challenges

In this chapter the key question: "*Which challenges are yet to be overcome if the logistics 4.0 is to be succesfully implemented in port communities?*" has been answered. The advantages of introducing logistics 4.0 applications seem abundant and clear. However, its implementation would not be without difficulties and there are certain challenges that must be dealt with, in order to make the implementation successful. For interorganizational applications it is important that there is a certain level of mutual trust between organizations. Without this trust it seems unlikely that organizations will fully commit to certain applications, such as the TradeLens. This mutual trust is also essential when it comes to data sharing. Individual organizations often do not possess enough failure data to really build valuable condition-based maintenance systems. Sharing data for similar components could be a great solution. Furthermore, the security of the data and operations are vital for each organization. In order to conduct operations in a safe and secure way, it is necessary that organizations pay close attention to their cyberrisk management systems. A second remaining challenge in the domain of security is the lack of great Big Data security tools. Finally, the social challenges must be addressed. Logistics 4.0 applications are often accompanied by automation, leading to the inevitable loss of certain jobs. Challenges in ethical questions remain, even though history tells us that new technologies create new jobs as well as destroy old ones. The dismissal of employees may be a very costly endeavour though and thus may create a barrier for certain applications.

[1] In Dutch: ontslag wegens bedrijfseconomische redenen

Chapter 6

Conclusion & Recommendation

In this chapter the conclusion and recommendation will be given. The conclusion will consists of reviewing the answered key questions and answering the main research question as stated in chapter 1. The recommendation will provide insights into further research that can be performed.

6.1 Conclusion

According to the International Maritime Organization (2013) [1] international shipping transports around 90% of global trade around the world. The global trade is expected to go up, as is presented in figure 1.2, which requires port communities to handle even larger amounts of cargo and ships. Also shippers are complaining about the lack of transparency in the global supply chain. Logistics 4.0 provides options to increase both the operational efficiency in the port community, which is needed to handle the rising throughput of cargo, and the supply chain transparency, in order to cater to the shipper's demand. This report has provided an overview of the port community, logistics 4.0, the applications of logistics 4.0 in the port community and the challenges it entails.

In chapter 2 it was defined which players make up the port community, what their goals are and which inter-relationships are present. The presented definition of the port community consists of the port authority, shipping lines, terminal operators, freight forwarders, shipping agents, customs, towage and pilotage companies, waste reception facilities, ship chandlers and repair services. The port authority aims to make the port as attractive as possible for shipping lines and industry. The shipping lines aim to deliver cheap services to their shippers and provide them with real-time information regarding the position and status of their goods. Terminal operators aim to make themselves as attractive as possible to shipping lines through low costs and efficient and reliable operations. Freight forwarders want to move as much cargo as they can for their client shippers. Customs aims to have control and knowledge over the flow of goods that enter and leave the port, while hindering the logistic processes as little as possible. Shipping agents act as middlemen between ships and the port community and aim to remain being able to conduct business. Shipping agents, towage and pilotage companies, waste reception facilities, ship chandlers and repair services provide services to ships entering and exiting the port and aim to keep it that way.

In chapter 3 it was discussed what logistics 4.0 is and what the technologies are that are enabling it. Logistics 4.0 centers around the automation of material handling and information handling and flow, with the key goals of increasing reliability, transparency and flexibility and decreasing complexity, risk, errors and transport costs. The technologies enabling these improvements were recognized to be: Internet of Things, RFID, Big Data, machine learning and the blockchain.

In chapter 4 multiple applications of logistics 4.0 in the port community were presented. It was also extensively discussed how these applications worked and could be implemented. The presented applications were: moving the global supply chain on the blockchain, the introduction of smart containers, condition-based maintenance strategies for both vessels and cranes, the automation of container terminals and the use of smart customs control.

In chapter 5 it was presented which challenges are yet to be overcome if logistics 4.0 is to be successfully implemented in port communities. The first challenge presented was to increase the level of mutual trust between organizations. The second challenge was to increase the level of cyber security for members of the port community. Cyber security is especially important for automated terminals, since a security breach could shut down all operations. Furthermore it was discussed that Big Data still holds challenges regarding its data security tools. Finally the social challenges were examined from an ethical and financial viewpoint.

The introduction of logistics 4.0 can make life better for port authorities, depending on their rate of adoption. If they are able to stimulate better integration of logistics 4.0 across their community, their competitiveness will rise. If they are not, their competitiveness might fall. Applications such as TradeLens will allow shipping lines to provide a much higher transparency for their shippers. Having the ability to offer a higher transparency than competitors, allows shipping lines to raise their rates. However, if all shipping lines gain access to the TradeLens (or similar applications), their competitive edge will disappear. Condition-based maintenance strategies will allow shipping lines to reduce their operational costs, thus leaving a higher profit margin. Due to the competitive nature of the shipping business, it is highly probable that this higher profit margin will not last and that shipping rates will be lowered for shippers to increase their competitiveness. Terminal operators will increase their operational efficiency due improved communication through applications such as TradeLens. They will be better able to estimate the arrival times of containers, which can be handled with automated equipment, whose maintenance costs can also be reduced through condition-based maintenance. It is the question whether the reduced operational costs, resulting from automation and smarter maintenance, will result in higher profits for the terminals or whether internal competition will diminish them by offering lower rates to shipping lines. It is unclear what the future of the freight forwarder looks like. As stated in chapter 2 the freight forwarder benefits from an intransparent supply chain. The introduction of TradeLens might make it possible for shippers to plan the transportation of their cargo themselves, which would make the freight forwarder obsolete. It is more likely however that such ease of transportation planning will not be reached and shippers will keep using freight forwarders. The introduction of TradeLens-like applications will however severely reduce the workload for the freight forwarder per cargo unit, which would result in lower prices for shippers. Since it will take less time for a freight forwarder to organize the cargo transportation, they will be able to take on more clients. This will result in fewer freight forwarders in total, where only the most competitive will remain in business. The shipping agent operates as the middleman between ships and port community. If all communications between parties can go directly and easier than before, there is a very good chance that they will become obsolete. It is likely that only few shipping agents will remain in business, acting as a responsible point of contact of large shipping lines, for the port community, in case of unusual situations. Customs will become more efficient in their operations, because of the better access to more reliable information on cargo, which logistics 4.0 provides for them. If this is combined with a more intelligent way of assessing which containers to inspect, general border security is bound to profit. Towage and pilotage companies, waste reception facilities, ship chandlers and repair services will probably not undergo severe changes, as their services are not easily automated. Information exchange between shipping lines and these companies will be improved. Ship chandlers can receive automatic orders for spare parts from shipping lines and repair services can receive automatic request for their services from shipping lines. Both could lead to slightly higher profit margins for them. In conclusion, for most members of the port community, adapting to logistics 4.0 is a requirement to stay competitive. The biggest advantages are for customs, whose operational efficiency can be greatly increased, and the shipper, to whom most of the profit margin will flow back and who can look forward to lower rates for shipping goods around the world.

6.2 Recommendation

Further research on the main research question: *"What possible applications does logistics 4.0 provide in port communities and how is the port community affected by them?"* can be subdivided in multiple territories. One is to research how some of the challenges to implementation, presented in chapter 5, can be overcome. Another is to broaden the scope of the port community, which was presented in chapter 2.

One of the challenges presented in chapter 5 concerned the lack of mutual trust between organizations. More research could be done on the benefits that an increased level of mutual trust, and perhaps even the sharing of data, provides for organizations in the port community. If there is a firm basis of scientific research to corroborate that all organizations stand to benefit, managers might be more tempted to try out closer collaborations.

Another of the challenges presented in chapter 5 concerned cyber security. It seems clear that further research is required in this area. Further research on how to guard oneself against cyber attacks and how to improve cyber management should take all five functional elements, as presented in section 5.2, into consideration, namely: identify, protect, detect, respond and recover.

In chapter 2 the scope of the port community was defined. For future research this scope could be widened by for instance, including hinterland transportation companies that are operational in the area. Logistics 4.0 applications for barges, trains and trucks could be researched, along with the effect that these applications would have on the port community. One example might be the introduction of autonomous road trucks, which is sure to have an impact on multiple members of the port community.

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