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Bachelor Thesis

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“Digital Transformation of Ports: A Status of the Port of Hamburg and the Port of Singapore”

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Abstract

The current third economic revolution urges organizations to digitally transform in their entirety. This implies that the use of technology will be increased in order to enhance organizational performance. Ports worldwide have to face a various number of challenges and meet them by taking measures of digitalization. The Port of Hamburg and the Port of Singapore took numerous measures in order to cope with these challenges and to remain attractive transshipment hubs and actors in supply chains. The implemented measures were analyzed and evaluated in order to determine a state of progress regarding digital transformation of both ports. The result shows that both ports are far advanced in terms of digitalization. However, the Port of Hamburg is slightly more advanced than the Port of Singapore. Nevertheless, both ports show potential for digital improvements. They have to catch up especially in terms of social network activity and the application of wearables, whereas the PoS should also focus on the use of apps and the "Internet of Things". In addition, it is recommended to both ports to always keep an eye on the development of competing ports and to increase the level of collaboration with them as well as with organizations of highly digitalized industries in order to get suggestions for further digitalization measures and the improvement of already implemented ones.

Keywords: Digital Transformation, Ports, Port of Hamburg, Port of Singapore, Digitalization, Future Developments

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List of Abbreviations

3D	Three-dimensional
AGV	Automatic Guided Vehicle
App	Application
B2B	Business-to-Business
B2C	Business-to-Consumer
BITKOM	Bundesverband Informationswirtschaft, Telekommunikation und neue Medien (Federal Association for Information Technology, Telecommunications and New Media)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry of Economics and Technology)
BNetzA	Bundesnetzagentur (Federal Network Agency)
CO_2	Carbon Dioxide
CPS	Cyber Physical System
CTA	Container Terminal Altenwerder
DIVA	Dynamic Traffic Volume Information System
DRMG	Double Rail Mounted Gantry Crane
DSL	Digital Subscriber Line
e.V.	Eingetragener Verein (Registered Association)
EVE	Effektive Verkehrslageermittlung (Effective depiction of the traffic situation)
EVITA	Eisenbahn-Verkehrs-Infrastruktur und Transport-Abwicklungssystem (Rail Traffic Information Operations System)
GDP	Gross Domestic Product
GPS	Global Positioning System
HABIS	Hafenbahn Betriebs- und Informationssystem
HHLA	Hamburger Hafen und Logistik AG
HPA	Hamburg Port Authority
HR	Human Resources

HSPA	High Speed Packet Access
ICT	Information and Communications Technology
ID	Identification, Identifier
IoT	Internet of Things
IT	Information Technology
Kbits/s	Kilobits per Second
LTE	Long Term Evolution
M2M	Machine-to-Machine
Mbit/s	Megabits per Second
MPA	Maritime and Port Authority of Singapore
OECD	Organisation for Economic Co-operation and Development
OHBC	Overhead Bridge Crane
PoH	Port of Hamburg
PoS	Port of Singapore
PRISE	Port River Information System Elbe
PSA	Port of Singapore Authority
RCOC	Remote Crane Operations & Control
RFID	Radio-Frequency-Identification
SMACT	Social, Mobile, Analytics, Cloud and Things
SPL	SmartPORT Logistics (mobile app)
TETRA	Terrestrial Trunked Radio
TEU	Twenty-foot Equivalent Unit
TLS	Terminal Logistics and Controlling
UMTS	Universal Mobile Telecommunications System
UN	United Nations
US	United States
V2X	Vehicle-to-X

VDMA	Verband Deutscher Maschinen- und Anlagenbau (Association of German Machinery and Equipment Constructors)
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie (Association of the Electrical Engineering and Electronics Industry)

1 Introduction

1.1 Research Problem

Over the past decades digitalization manifested in the global economy. Within the digital age "the world is making the transition from an industrial society to an information society" (Stadler, et al., 2014, p. 18). Industries and companies are urged to digitally transform their businesses leading to changes in strategies, processes, structures, products and cultures in order to deal with more stringent requirements of the business environment.[1] In future, humans, machines and resources communicate directly and in real time with each other, enabled through innovative technologies, cheaper and faster internet connections and new possibilities of information and data transfer. This generates increasing amounts of data being transmitted, progressed and analyzed.

Digital transformation, as the adoption of technologies to enhance organizational performance, appears as a critical process across various industries worldwide,[2] inter alia the shipping industry. Ports, notably the Port of Hamburg and the Port of Singapore, are being digitalized in order to cope with current and future challenges pursuing the objective of staying competitive through cost reduction and increasing efficiency.[3]

Since digital transformation is a continuously ongoing process, this bachelor thesis aims at determining a current status of the Port of Hamburg and the Port of Singapore regarding digital transformation and the progress in implementing measures of digitalization in order to cope with challenges and future trends in seaborne trade and related port operations. Additionally, it aims at providing derived recommendations for digital future developments for both ports.

[1] Westerman, et al., 2011, p. 5; cf. Bloching, et al., 2015, pp. 17 ff.
[2] Bloching, et al., 2015, pp. 17 ff.
[3] Markovitch & Willmott, 2014

1.2 Way of Investigation

As this bachelor thesis deals with the digital transformation of the Port of Hamburg and the Port of Singapore, chapter two focuses on the concept of digital transformation. Both meaning and development of digital transformation will be examined closer. Furthermore, it deals with the levers of digital transformation and presents corresponding enabler technologies. Chapter three targets main challenges ports have to face nowadays and in future. These will be explained briefly. Thereafter, chapter four introduces and presents the Port of Hamburg and the Port of Singapore. General information as well as information regarding turnover volume developments will be given. In addition, major characteristics and current issues will be described. Afterwards, in chapter five, various measures in terms of digitalization of both ports will be described. These measures are assigned to and sorted by particular processes and main interest areas of ports. Chapter six provides an evaluation of the measures which have been or will be implemented in the near future. By the end of this chapter, recommendations for both ports and their future developments will be depicted. In chapter seven, a summary of the findings as well as a critical acclaim and an outlook will be given.

2 Digital Transformation

2.1 Core Idea and Development of Digital Transformation

The past 250 years were shaped by two economic revolutions which were influenced by new technologies that affected and changed the way business was made, the way people lived, worked and communicated with each other as well as the development of certain industries.

The first wave, the Industrial Revolution, took place between 1760 and 1830. It is characterized by the replacement of handcraft production through the use machines as for example in the textile industry. The second wave, the Technological Revolution, took place between mid-19th century and the World War I. This time "was characterized by the building of railways, the beginning of electricity and electrical means of communication such as telegraph, telephone and radio as well as mass production and the production line" (Schmitt, 2015, p. 161). Both economic revolutions influenced and transformed the economies "from agricultural to industrial and, ultimately, service economies" (Schmitt, 2015, p. 161).

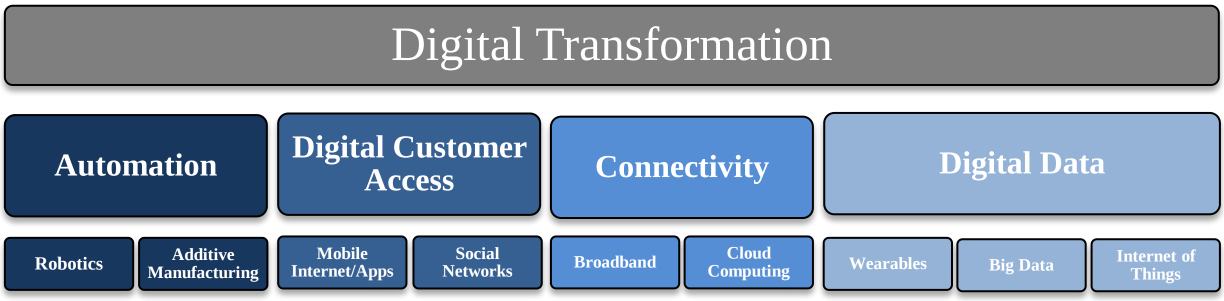
We are currently in the midst of the Third Great Wave, meaning the third economic revolution. This wave is again characterized by new technologies influencing both businesses and people.[4] This revolution implies a radical change from a company to a fully networked digital organization.[5] Digital Transformation describes „the use of technology to radically improve performance of enterprises".[6] The meaning of "digital" as an economic term stands for "based on digital technologies or digital techniques" compared to different meanings in other fields. In the narrower sense, this implies the so-called SMACT-technologies[7] – Social, Mobile, Analytics, Cloud and (Internet-of-) Things[8]. These new technologies and applications urge enterprises to reshape an increasing number of processes and process elements within the business and to develop strategies and adapt these processes to requirements, such as real-time and connectivity, of the digital economy.[9] The SMACT-technologies can be classified

[4] Schmitt, 2015, pp. 161 ff.
[5] Büst, 2015
[6] Westerman, et al., 2011, p. 5
[7] Tank, 2015
[8] van Manen, et al., 2014, p. 6
[9] Büst, 2015; Yoo, et al., 2010, pp. 3 ff.

into four categories which are the levers of digital transformation. Both levers and corresponding enabler technologies are illustrated in Figure 1.

In the following chapter 2.2, the levers of digital transformation and corresponding enabler technologies will be examined in more detail.

Figure 1: Levers of Digital Transformation and Corresponding Enabler Technologies



Source: Based on Bloching, et al., 2015, p. 20

The availability of digital mass data, the automation of production processes, the connection of value chains and the development of digital customer interfaces lead to a transformation of business models and to a reorganization of entire industries.[10] The overall aim is to couple digital technology with integrated information in order to achieve global synergies while not losing local responsiveness.[11] In order to be successful in digitally transforming businesses it is necessary to change the way of thinking from a functional oriented to a more process-oriented way, which ensures an optimization of operational practices.[12] Moreover, "digital business transformation is about leadership. It is the ultimate challenge in change management because it impacts all organizational levels of an enterprise and its extended supply chain. The transformation starts with redefining the firm's strategic vision – that is, the shared composite of goals, competencies, and capabilities a firm deploys to create and sustain competitive advantage" (Bowersox, et al., 2005, p. 2).

[10] Bloching, et al., 2015, pp. 19 f.
[11] Westerman, et al., 2011, p. 23
[12] Balaraj, 2011, p. 7

2.2 Levers of Digital Transformation and Corresponding Enabler Technologies as Driving Forces and Trends of the Digital Age

2.2.1 Automation

The digital transformation influences and changes the functionality of machines. The combination of conventional technologies and artificial intelligence enables the development of independently working, self-organizing systems which decrease error rates, increase the performance and reduce operating costs.[13]

Automation in general describes the transfer of functions of (manufacturing) processes, especially process control and process regulation tasks, from human to artificial systems. Automation is the result of automating, particularly the usage of automatic systems. These systems are artificial systems which autonomously operate a program and, based on this program, make decisions regarding control and regulations of processes. Automatic processes follow a loop principle which implies a goal-oriented influence on processes by feedback of control results.

There are two different types of automation, partial and full automation, indicating the extent of automation and therefore the extent to which manpower is involved in these processes. Furthermore, by means of automation, an increase in productivity and flexibility as well as a generally enhanced efficiency should be achieved. Machining and processing operations, conveying, handling and storage operations as well as development, production planning and production control processes can be automated.[14]

Robots allow for automation. A robot is a machine that resembles humans either in its appearance or its functionality. Nowadays, robots have to fulfill higher demands. A robot once had to fulfill only minimal requirements such as the possibility to move itself and/or physical objects, possessing wheels or legs if the robot had to be mobile or owning a memory system in order to save instructions.

[13] Bloching, et al., 2015, pp. 19 ff.
[14] Voigt, n.d.

These minimal requirements were extended to the following attributes:

- Delegation: a robot performs tasks to which it was explicitly authorized by another robot or user
- Communication skills: a robot should communicate with its user regarding receiving instructions and giving feedback about status of the task
- Autonomy: a robot works independently
- Monitoring and action: a robot has to monitor its operation environment and has to influence the environment actively through its actions
- Activity orientation: a robot has to interpret the monitored events in order to take relevant decisions itself

There are robot systems for various applications. Numerous types of industry are inconceivable with robot systems and are reliant on them since they perform tasks like installing, welding, cutting, coating, pressing, packaging or transporting. Industry robots work due to an interaction of various technologies: drive, navigation, sensor, mechanic and information technology.[15]

Moreover, additive manufacturing, also called 3D print, represents another enabler technology of automation.[16] “Additive manufacturing […] is a process of making a three-dimensional solid object of virtually any shape from a digital model” (Roland Berger Strategy Consultants, 2013, p. 7). It is called “additive” since successive layers of a material are applied instead of removing parts of material by cutting, drilling or bashing in order to shape material to a part.[17] A digital model is either drawn up by a designer or is created by a 3D scan. The information of the digital model’s shape is communicated to the printer. The printer interprets the information and adds layer by layer until the part is completed.[18] Additive manufacturing enables an optimization of designs, including new geometric shapes which could not have been produced with traditional methods, combined with a weight reduction. This type of processing was initially used as a cheap and fast alternative for the production of prototypes. Nowadays, different materials, such as metals, polymers and waxes, can be processed through

[15] Haun, 2013, pp. 9 ff.
[16] Bloching, et al., 2015, p. 20
[17] The Economist, 2011
[18] PwC and Manufacturing Institute, 2014, p. 1

different technologies. This is the reason why additive manufacturing is also used for the production of final products these days.[19]

2.2.2 Digital Customer Access

The mobile internet enables new intermediaries to obtain direct customer access, which allows for full transparency and the offer of innovative services.[20] In 2015, more devices accessed online data than people were living on earth. In fact, more than 10 billion devices were connected to the internet and this number is continuously increasing.[21] Forecasts assume the number of mobile devices to amount 34 billion by 2020. Conventional computing devices like smartphones, tablets and smartwatches will make up 10 billion, whereas Internet of Things (IoT) devices (see chapter 2.2.4) will account for 24 billion.[22]

However, the web we used to know is changing. "Rapid advances in mobile technologies now allow consumers to interact, create, and share content on the internet regardless of their physical location. This kind of ubiquitous access to the internet through a mobile device is known as mobile internet. Dramatic growth in mobile activities has led to a corresponding torrent of granular data that captures these behaviours. Besides smart phones, increasingly tablet computers and intermediate mobile devices like iPads enable access to the mobile internet" (The Financial Times Ltd., n.d.).

Moreover, applications (apps) play a significant role in the ongoing change. According to Kosner (2012) this is termed as "Appification of Everything", whereas Lilljequist (2012) calls it the "Appification of the Web". Apps have changed the way we deal with online content. Users tend to approach their app first before approaching the mobile web. 86 percent of all users spend their mobile time in apps and only 14 percent in the browser-based web. Therefore, apps serve as an important B2B as well as B2C communication platform since they

[19] Roland Berger Strategy Consultants, 2013, pp. 7 ff.; The Economist, 2011
[20] Bloching, et al., 2015, p. 19
[21] Schwarz, 2015, p. 19
[22] Camhi, 2015

facilitate interaction among all stakeholders along the value chain of organizations. Furthermore, apps increase brand loyalty if its user is satisfied with the app.[23]

Social networks belong to social media and aim at enabling social interactions. They serve as a new communication channel and improve both communication and collaboration.[24] "Organizations are not using social networks only to listen to and better understand customer sentiment about products, brands, and companies as a whole. They are also using social technologies for recruiting and HR management" (Cray, 2014, p. 9).

2.2.3 Connectivity

The first enabler technology, broadband, refers to a digital information and communication technology. It allows for a fast and simultaneous signal transmission through numerous independent pathways within one wire or cable and the interconnection of various devices on a network. Signals which are transmitted can be data like audio, video, graphics, text, etc. Thereby, the formerly significantly slower single-channel technology, the narrowband technology, was widely replaced by this new technology.[25] There is no uniform definition of broadband. According to the Organization for Economic Co-operation and Development, in short OECD, the transmission rate of uploads has to be at least 128 Kbits/s, the one of downloads 256 Kbits/s, whereas the American Federal Communications Commission sets a minimum transmission rate of 200 Kbits/s. The BMWi (German Federal Ministry for Economic Affairs and Energy) and the BNetzA (Federal Network Agency) define a transmission rate of 128 Kbits/s as broadband connection. In Canada, 64 Kbits/s are sufficient in order to refer to as broadband connection.[26]

Broadband technologies can be either wireless, for example satellite, UMTS (Universal Mobile Telecommunications System), HSPA (High Speed Packet Access), LTE (Long Term Evolution) or WLAN (Wireless Local Area Network) or with a wired connection, for example DSL (Digital Subscriber Line), optical fiber or the possibility to connect via TV cable.[27] An

[23] Wächter, 2016, pp. 120 ff.; Cray, 2014, p. 3
[24] Cray, 2014, pp. 3 ff.
[25] WebFinance Inc., n.d.
[26] Bach, 2008, pp. 11 f.
[27] Bundesministerium für Verkehr und digitale Infrastruktur, n.d.

overview of particular broadband technologies and their functionalities can be found in the appendix (A1).

Cloud Computing, the second enabler technology of “connectivity”, incorporates technologies and business models in order to dynamically provide IT-resources like networks, servers and data storage, applications and services. They are flexible and demand-oriented available via the internet or intranet and substitute convenient data centers[28] since the convenient hardware architecture has been widely moved into the cloud. Software products undergo a transition from rigid desktop solutions, attached to traditional annual software licensing and eventually including limited installation rights for end devices, towards applications that are accessible from numerous client devices and only have to be paid if used. Therefore, clouds allow for location independence as all virtual resources are bundled in the cloud and enable data exchange and connection between users. In addition, cloud services are measurable and can be controlled and reported, likewise providing transparency to the consumer and the provider of mobile services.[29]

2.2.4 Digital Data

The first enabler technology of digital data is “wearables”. Wearables, also called wearable technologies or wearable computers, are computer technologies which are worn or carried on the body or on the head[30] “while still having the user interface ready for use at all times” (Malmivaara, 2009, p. 4). They have the purpose of supporting a real-world activity, for examples by providing (additional) information, evaluations and instructions. Advanced sensor technology, continuous data processing and support of the user are essential to wearables. Examples of wearable technologies are intelligent bracelets, particular clothes with additional functions, smartwatches as well as data glasses. They are able to collect body data combined with other data concerning time and space, analyze and document the gathered data and share the information with others. Some tools are even able to use augmented reality. Augmented reality refers to the perception of the real world and an extension of this perception by the addition of virtual aspects by means of computers. Images of the real world

[28] Leymann, n.d.
[29] Mell & Grance, 2011, p. 2; Leymann, n.d.
[30] Bendel, n.d.; Malmivaara, 2009, p. 4

are displayed on smartphones or data glasses and texts or other images will be inserted. This technology is used, for example, in logistics and production.[31]

Big Data, the second enabler technology of digital data, is not defined uniformly. However, many definitions assign Big Data the characteristics "volume, velocity and variety". Through the "Internet of Things", which will be described at the end of this chapter, the degree of connectivity between humans and things, as well as things and things, is expanding. This leads to a continuously increasing volume of data.[32] The collection, processing and evaluation of digitized mass data enable improved predictions and an improved decision-making.[33] Velocity is not interpreted uniformly. On the one hand, velocity describes the speed of generating new data; on the other hand, it describes the speed of data modification. Furthermore, velocity describes the transience of data. Circumstances which are described by digital data change faster and faster. Therefore, new or changed data has to be added constantly. Variety describes the heterogeneity of data sources and data formats since Big Data stems from a variety of different sources in different formats. It is a core task of Big Data to gain comprehensive insights from different sources and formats.[34]

The third enabler technology is the Internet of Things (IoT). Industry 4.0 is being discussed often in recent days. It describes the 4th revolution of the industrialization.[35] There is no clear definition of Industry 4.0 yet. However, according to the "Plattform Industrie 4.0", a joint project of the German trade associations BITKOM e.V., VDMA e.V. and ZVEI e.V.,[36] the focus of Industry 4.0 is on real-time capable, intelligent, horizontal and vertical networking of humans, machines, objects and ICT systems for a dynamic management of complex systems.[37]

The internet is being regarded as driver for a further integration of the real and the virtual world. The vision is the Internet of Things, Data and Services. The things, namely products, production facilities and tools, receive an internet address, microprocessors and sensors and thus become intelligent objects in the physical world. Wireless networks like RFID and WLAN appear as possible data transfer methods, whereas services on internet servers process

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[31] Markgraf, n.d.; Bendel, n.d.
[32] Auschitzky, et al., 2014; Dorschel, 2015, p. 7
[33] Bloching, et al., 2015, p. 19; cf. Cray, 2014, p. 3
[34] Dorschel, 2015, pp. 7 f.
[35] Fricke, et al., 2014, p. 6
[36] Plattform Industrie 4.0, 2015
[37] Bauer, et al., 2014, p. 18

the received data. Cyber Physical Systems (CPS) serve as basis of Industry 4.0. CPSs are software-intensive, embedded systems, which are able to connect across various industries with services worldwide.[38]

Embedded systems are computer systems which are embedded in devices, facilities and machines, e.g. microcontrollers, communication systems, identifiers (barcode or RFID-transponders), sensors and actors.[39] The microcontroller represents the intelligence of the embedded system and analyzes incoming data, determines the object's status, prepares decisions and, finally, carries them out. Communication systems ensure the interaction with networks and sensors supply data of the object's direct environment.[40] The usage of sensors led to new opportunities of how data can be gathered. Not only machines are affected, but also customer interfaces, as data can be now collected within vehicles or through the use of smartphones, tablets and other portable devices. Modern analysis techniques make a fast and detailed data evaluation possible which enables real-time reactions to certain circumstances, for example in logistics, as it is possible to adapt routes of transport vehicles to current traffic situations in real time.[41] Identifiers ensure an unambiguous identification of the object and actors perform movements of the object and transmit visual or acoustic information.[42] Thus, CPSs offer numerous application possibilities.[43]

Industry 4.0 is a step ahead of automation. The named embedded systems should give machines the ability to interact (M2M-communication) and to carry out self-analyses and self-configurations allowing them to self-optimize along the whole value chain. Processes will no longer be centralized controlled, but decentralized by respective machines.[44]

[38] Dorst, 2012, pp. 35 f.; cf. Min, 2012, pp. 103 ff.
[39] DATACOM Buchverlag GmbH, n.d.; Bauer, et al., 2014, p. 19
[40] Bauer, et al., 2014, p. 19
[41] Bloching, et al., 2015, p. 23
[42] Bauer, et al., 2014, p. 19
[43] Dorst, 2012, p. 36
[44] Handelskammer Hamburg; Hamburger Dialogplattform Industrie 4.0, 2015, p. 3

3 Challenges and Future Trends in Seaborne Trade Affecting Ports and Their Developments

3.1 Intermodal Linkages

Ports are important hubs in supply chains. Their main activities are unloading and loading cargo carriers on the water side. However, the onward transport of cargo via trucks on the road, rails or barges is also in the port's field of activity.[45] The cargo transport with two or more transport modes without the exchange of the transport container is called intermodal transport. Intermodal transport aims at making use of each mode's specific advantages while enabling an uninterrupted and fast transportation chain from sender to receiver.[46] Intermodal linkages might lead to congestion if not managed appropriately. Congestion is about the impediment of other actors in the supply chain due to the behavior of another actor or other actors. It has a high impact on the whole transport as well as the general throughput performance and thus influences the competitiveness of ports since congestion leads to higher "queuing costs". These additional costs have to be paid by a third party and consist, inter alia, of time loss and additional fuel consumption. Hence, these interruptions and delays have to be avoided as far as possible.[47]

3.2 IT and Technology

Business life and industrial processes are inconceivable without IT and technology.[48] "Flows of information surrounding the flow of physical cargo and related processes are important both for tracking progress and controlling logistics chains. Moreover, ICT applications act as enablers for improved management of employed resources" (Asbjørnslett, et al., 2012, p. 134). Examples for the use of IT in ports are electronic document transmission which optimizes cargo handling in ports and truck appointment systems, which reduce delays in

[45] Meersman, et al., 2012, p. 50
[46] Krieger, n.d.
[47] Meersman, et al., 2012, pp. 50 ff.
[48] Haun, 2013, p. 10

hinterland transport.[49] Since IT and technology allow for automation (see chapter 2.2.1) and enable optimization in operations and processes through the trends of, inter alia, Big Data (see 2.2.4) and Cloud Computing (see chapter 2.2.3), both will become even more important in port operations.

3.3 Safety and Environmental Protection

Due to increasing vessel sizes, future port developments also have to focus on safety in ports. This includes navigational safety and ensuring safe movements of all ships in the waters by enhanced coordination.[50] Furthermore, not only safety in waters is important to ports but safety on land, too (see for example chapter 5.1). This leads to an increasing number of automated processes on land in order to ensure worker's as well as good's safety and to the application of more process surveillance technologies (see chapter 5.7).

Moreover, environmental protection and sustainability are important issues these days. The UNs' target is to keep the increase of global temperature below 2 degrees Celsius,[51] which requires a worldwide emission reduction at least by half from levels in 1990 by 2050. According to the International Maritime Organization, seaborne trade is responsible for 2.5 percent of all greenhouse gas emissions and this number is forecasted to increase between 50 and 250 percent by 2050 which depends on energy and economic developments. Through the use of existing as well as innovative technologies and operational changes, the CO_2 emissions of ports should be reduced.[52]

[49] Meersman, et al., 2012, p. 57
[50] Yip, 2008, pp. 190 f.
[51] United Nations, 2009, p. 9
[52] European Commission, 2015

3.4 Changing Production Trends and Consumption of Materials and Goods

Ports are highly influenced by consumption and production trends of goods and materials worldwide. 3D printing as a production possibility will reduce the necessity of shipping products, parts and raw materials to market in future even more since they can be produced and processed locally. According to Tipping, Duiven and Schmahl, 37 percent of sea container shipments are endangered by this technology.[53] Additionally, the further economic development of a country usually leads to improvements regarding food supply. Consumers become more demanding and can afford to buy more expensive and imported products,[54] which leads to an increase in shipping. However, not only food is affected. Manufacturing and technology are also improving when emerging countries develop, leading to increasing export numbers of, for example, advanced technology products.[55]

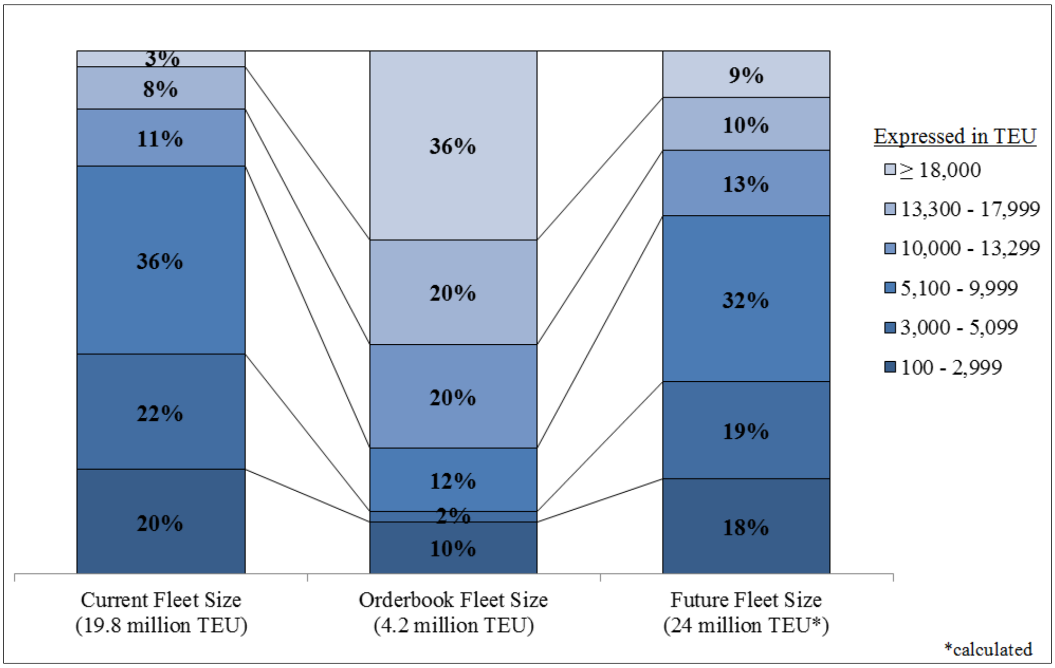
3.5 Increase in Size of Container Vessels

Container vessels are becoming ever larger and the number of these vessels is increasing which is probably the greatest challenge ports have to face globally. Figure 2 shows three bars presenting the current fleet capacity by vessel size in percent, the ordered fleet capacity by vessel size in percent as well as the future total fleet capacity by vessel size in percent (as of November 2015). The current global fleet size amounts 19.8 million Twenty-foot Equivalent Unit (TEU). Additional vessels with an overall capacity of 4.2 million TEUs are ordered. Currently, more than 75 percent, which makes more than 15 million TEUs, are allocated on vessels with a capacity of 100 to 9,999 TEUs and only 3 percent, 594,000 TEUs can be assigned to vessels with a capacity of 18,000 or more TEUs. The order of very and ultra large container vessels is dominating. More than three quarters of ordered vessels comprise sizes from 10,000 TEUs to more than 18,000 TEUs. If summing up the numbers of the current global fleet size and the numbers of the ordered fleet size, the result is a future fleet size. What can be recognized is the total increase of the share of vessels with a capacity of 13,300

[53] Tipping, et al., n.d.
[54] Food and Agriculture Organization of the United Nations, 2002; cf. Merk, 2014, p. 24
[55] Lun, et al., 2010, pp. 5 f.

TEUs or greater by almost 100 percent, whereas the share of vessels with a capacity of 18,000 or more TEUs shows an increase of 200 percent.

Figure 2: Development of Fleet Capacity by Vessel Size



Source: Based on Schmidt, 2015, p. 22 as by 2015; see appendix A2 for calculation

The increasing vessel size presents new challenges to ports regarding infrastructure as well as superstructure and operations. It requires more and higher container gantry cranes with longer outreaches on quay side and deeper port basins.[56] Furthermore, the growth of vessel sizes leads to growth of ports and terminals, if possible. The increasing number of arriving cargo leads to higher peaks of cargo and the need for increased terminal productivity. Therefore, efficient port transactions as well as efficient land-side connections are needed in order to stay competitive.[57]

[56] Schmidt, 2015, p. 23
[57] Naruse, 2015, p. 10

4 Presentation of Two Global Ports

4.1 The Port of Hamburg

4.1.1 Background Information

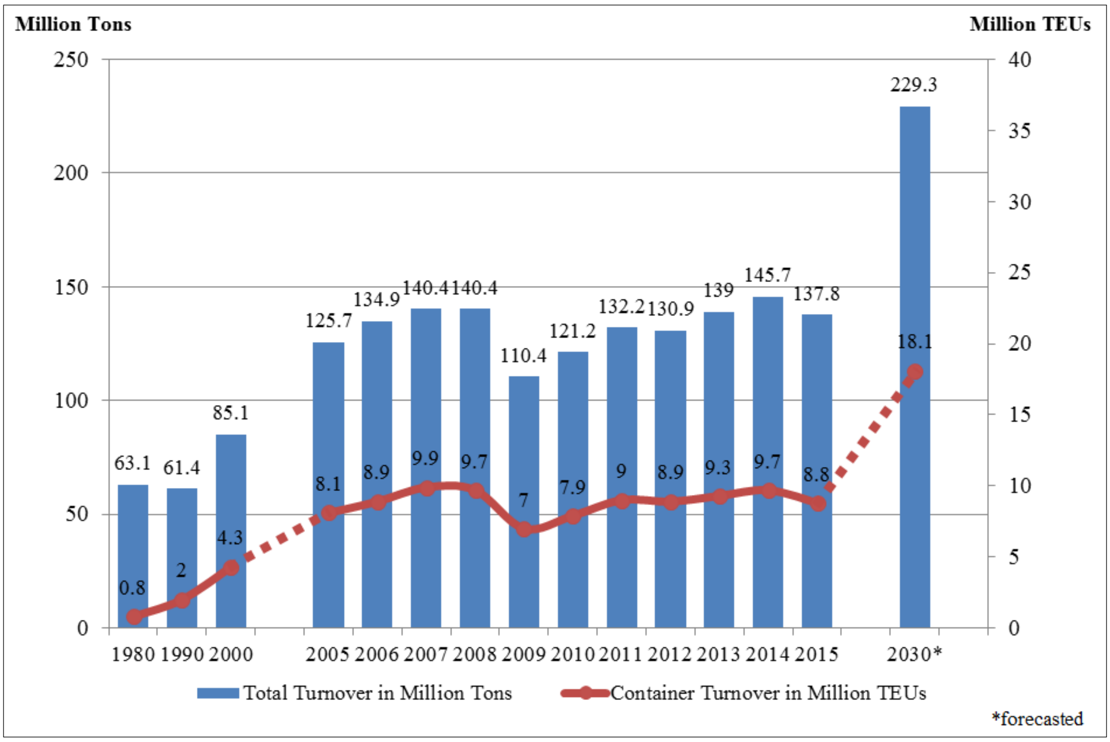
The Port of Hamburg (PoH) is one of the most flexible and high-performing universal ports worldwide with a long history dating back to the 9th century.[58] It is an inland port located in Hamburg in Germany and encompasses a port area of 7,200ha in total with 49km of quay walls.[59] The PoH is the most import transport hub in the North of Europe and, as it connects 950 ports in 178 countries worldwide, it is also called “Gateway to the World”.[60] Besides waterside connections for large vessels the PoH offers well-developed hinterland connections allowing for transport by rail, barge and truck.[61] As by 2014, the PoH was ranked as number 15 among the top world container ports with a transshipment volume of 9.7 million TEUs[62] and as number two among the top European container ports, right behind the Port of Rotterdam in the Netherlands. Therefore, it is of major importance for the German economy and created added value of 20.6 billion Euros in 2010.[63] The Container Terminal Altenwerder (CTA) is one of the most modern, technologically advanced and efficient container terminals in the world and is operated by the Hamburger Hafen und Logistik AG (HHLA).[64] The port’s three main trading partners are China, Russia and Singapore. A table including the top ten trading partners of the PoH and the number of traded TEUs can be found in the appendix (A3).[65]

[58] Hamburg Chamber of Commerce, n.d.; Hafen Hamburg Marketing e.V., n.d.
[59] Hamburg Port Authority [1], 2012, p. 8; Hamburg Port Authority [1], n.d.
[60] Hamburg Port Authority [1], n.d.; Hamburg Chamber of Commerce, n.d.
[61] Hamburg Port Authority [1], 2012, p. 12
[62] Hafen Hamburg Marketing , 2014
[63] Hamburg Port Authority [1], 2012, p. 9
[64] Port of Hamburg [1], n.d.
[65] Port of Hamburg Marketing, 2015, p. 36

4.1.2 Cargo Turnover Developments

Compared to its European competitors, the PoH reached above-average growth in cargo throughput in 2014.[66] Figure 3 shows the turnover developments of the PoH from 1980 to 2030 (forecasted). Containers are measured in TEU, whereas the total turnover including liquid cargo, suction cargo, grab cargo, break bulk cargo and containers is measured in tons.[67]

Figure 3: Total Cargo Turnover and Container Turnover Developments of the PoH from 1980 to 2030 (forecasted)



Source: Based on Institut für Seeverkehrswirtschaft und Logistik; IHS Global Insight Deutschland GmbH; Raven Trading, 2010, p. 97; Hamburg Chamber of Commerce, 2015, p. 4; Port of Hamburg, 2016

Both the total turnover as well as the container turnover show almost steadily upward trends from 1980 to 2007, rising from 63.1 million tons to 140.4 million tons total turnover and from 0.8 million TEUs being handled in the PoH to 9.9 million TEUs. In the following two years, a decrease of both had to be recorded. The total turnover declined by 30 million tons, the container turnover decreased by 2.9 million TEUs due to the financial crisis.[68] However, from that time onwards, a continuous increase in turnover volumes can be recognized until 2015.

[66] Port of Hamburg, 2015
[67] Hafen Hamburg Marketing; HPA, 2015, pp. 13 ff.
[68] Biermann & Teuber, 2012, p. 7

The PoH reached its seaborne cargo handling peak in 2014 with 145.7 million tons of total turnover and 9.7 million TEUs. From 1980 to 2005, the total turnover almost doubled from 63.1 to 125.7 million tons. In 2015, the total turnover decreased by 7.9 million tons and the container turnover showed a decrease of 0.9 million TEUs. This decline can be explained by a general decline of cargo volumes being handled in China, Russia and Poland.[69] The development for the next 25 years from 2005 on forecasts again an increase by more than 80 percent of the total turnover to 229.3 million tons and 18.1 million TEUs in 2030. This prediction is made under the assumption of a neutral economic development. The increasing turnover numbers will challenge especially the PoH as inland port due to its limited port area and limited possibility to expand.

4.1.3 Hinterland Transport

The PoH offers well-developed hinterland connections. Cargo can be either transported by truck, barge or rail into the hinterland. A figure presenting the hinterland connections of the PoH can be found in the appendix (A4). Its geographical position 130km inland is advantageous to the port of Hamburg since it allows for less expensive and environmentally friendly waterborne transport compared to transport on the road. Moreover, it is Europe's biggest rail port. Almost 12 percent of all German cargo transports by rail have their starting or ending point in the PoH.

The usage of various transport modes is called modal split. The modal split of a port is influenced by various factors such as the cargo structure, regular railway/inland waterway vessel services, port and hinterland infrastructure as well as customer requirements regarding costs, reliability and flexibility.[70] In 2014, 5.8 million TEUs were transported to the hinterland and 3.9 million TEUs were transshipped. This leads to a hinterland-transshipment-ratio of 60 to 40 percent. The hinterland container traffic is split up into the following shares of transport modes: 59.4 percent of all hinterland containers were transported by truck, 38.6 percent by rail and 2 percent by barge.[71]

[69] Port of Hamburg, 2016
[70] Hamburg Port Authority [1], 2012, pp. 12 ff.
[71] Hamburg Chamber of Commerce, 2015, p. 18

The forecast of 2025 shows not only an increasing quantity of containers and cargo to be handled, but also a change regarding the shares of modal usage in hinterland transports. The share of trucks will decrease by 2.4 percent to 57 percent, whereas the share of railways will increase by 2.4 percent to 41 percent. The usage of inland waterway vessels will remain the same. The increase in transport by rail is due to the overall increase of cargo to be transported and cost issues. In order to cope with the increasing volumes of freight, the Hamburg Port Authority (HPA) pushes the realization of projects regarding upgrades of transport infrastructure in the PoH.[72]

4.1.4 SmartPORT Hamburg Project

The smartPORT Hamburg is a project of the HPA affecting the PoH. It is divided into smartPORT energy which incorporates 15 subprojects and smartPORT logistics which incorporates 20 subprojects. The project aims at creating an intelligent port which consists of an intelligent network of processes, people and things in order to achieve operational excellence but with lower environmental impact.[73]

According to the HPA, the “smart port development requires a certain amount of courage and a great deal of innovative thinking. The HPA’s smartPORT philosophy combines both. Modern IT-supported transport and communications systems help to accelerate traffic and trade flows in the port and coordinate them more efficiently. At the same time, the HPA is committed to using renewable energy and saving resources in the port. In this way, the port can grow in a sustainable manner and remain one of the key economic drivers for Hamburg, the metropolitan region and beyond” (Hamburg Port Authority [1], 2015, p. 1).

SmartPORT energy aims at transforming the PoH to a port with “innovative, economically and ecologically viable supply of energy” (Hamburg Port Authority [3], n.d., p. 3). One goal is to expand renewable energy sources. Furthermore, the consumption of energy and resources in the PoH should be reduced.[74]

[72] Hamburg Port Authority [1], 2012, p. 24
[73] Westermann, 2015, p. 11 f.
[74] Hamburg Port Authority [3], n.d., p. 3

SmartPORT logistics is placed under the motto “Intelligent Networks and smart Sensors for a more efficient Port Management” (Hamburg Port Authority [2], n.d., p. 2). The focus is on three pillars: infrastructure, traffic flows and trade flows. An intelligent infrastructure is a prerequisite of efficient and frictionless traffic flows as well as trade flows. A higher efficiency in traffic flows is ensured by an intermodal Port Traffic Center which connects the numerous transport modes with each other. Optimal trade flows are ensured by excellent information flows and by having the right information exactly when and where it is needed.[75]

In order to realize the set targets for a sustainable and more efficient port, the digitalization of the PoH was pushed further. In chapter 5, the individual digitalization measures will be examined in more detail.

4.2 The Port of Singapore

4.2.1 Background Information

The Port of Singapore (PoS) is a relatively new harbor since it was founded as a free port at the beginning of the 19th century.[76] It is located in Southeast Asia, on the southern end of Malay Peninsula.[77] The PoS is connected to more than 600 ports in 123 countries[78] and is also called “Gateway to Asia” due to its major importance for the continent. In addition, it accounts for around 7 percent, 21.55 billion US-Dollars in year 2014, of the Republic of Singapore’s GDP.[79] Singapore always ranked as number one among the list of the top world container ports until 2010, when the Port of Shanghai outpaced the PoS.[80] From that year on, the PoS has always been ranked as number two among the top world container ports, as for example in 2014, with a transshipment volume of 33.9 million TEUs.[81]

[75] Hamburg Port Authority [2], n.d., p. 3
[76] Port of Singapore Authority [1], n.d.
[77] Yong, Tan Tai, 2009, p. 213
[78] The Maritime and Port Authority of Singapore [1], n.d.; cf. Möller, 2013, p. 241
[79] The Maritime and Port Authority of Singapore [2], n.d.; World Bank Group, 2015
[80] International Association of Ports and Harbors, 2014
[81] Hafen Hamburg Marketing , 2014; cf. Möller, 2013, p. 241

The PoS is one of the most efficient and busiest ports in the world, holding a top position in transshipment container throughput, bunker sales as well as annual number of vessel arrivals by shipping tonnage. Moreover, it operates as the busiest transshipment hub of containers since around 85 percent of all containers arriving in Singapore are transshipped to another port of destination. This still leads to a couple of millions of TEUs being transported to the hinterland. Hinterland transportation is mainly carried out by road haulage and barging.[82] The Port of Singapore Authority Corporation Limited operates five terminals: Brani, Keppel, Tanjong Pagar, Pasir Panjang Terminal 1 and Pasir Panjang Terminal 2[83] of which those at Pasir Panjang are the most advanced ones regarding suprastructure and technology.[84] In addition, Jurong Port Pte Ltd. operates the terminal located in Jurong.[85]

Singapore's port shows the highest efficiency in the process of customs clearance in Asia besides Hong Kong. It is predestined for the shortest time lead of customs clearance at lowest costs and the lowest number of documents in this process.[86] Furthermore, Singapore replaced Germany as worldwide best logistics location for the first time in 2012.[87]

4.2.2 Cargo Turnover Developments

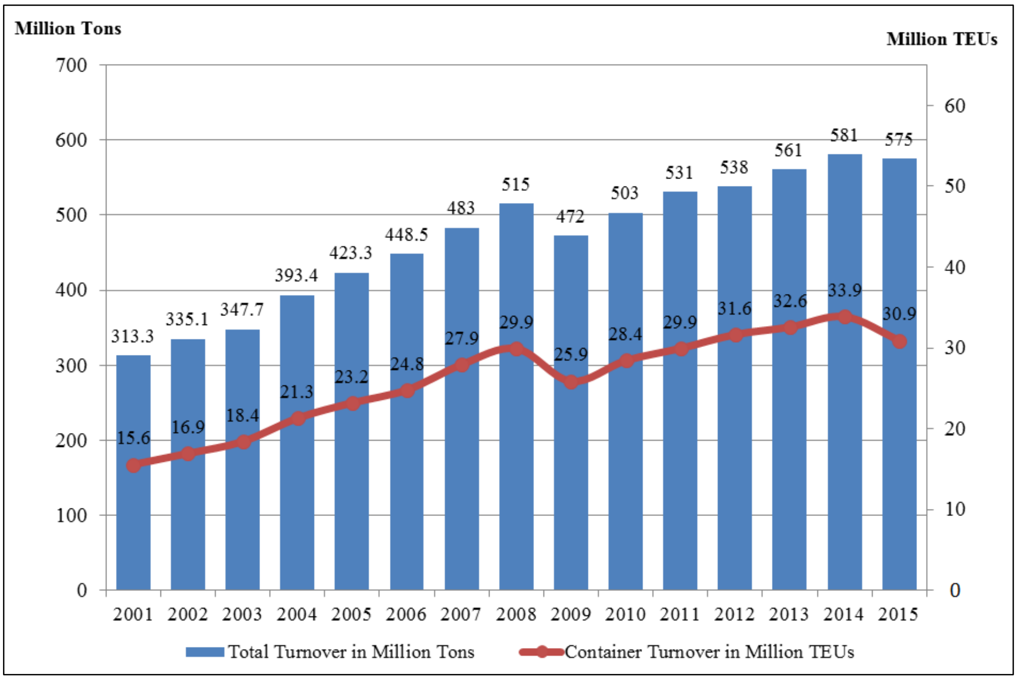
The PoS is mainly dependent on cargo transshipment instead of other ports which pursue large-scale hinterland transports. Due to longer development processes of hinterland connections, transshipment ports show a faster economic growth. Therefore, the competition for transshipment ports is intense and developments can be very volatile.[88]

Figure 4 shows the cargo turnover developments of the PoS from 2001 to 2015. Containers are measured in TEU, whereas the total turnover including all different kind of cargo is measured in tons. Both the total cargo turnover and the container turnover show a continuous increase in volumes from 2001 to 2008, rising from 313.3 million tons to 515 million tons total turnover and a container turnover rising from 15.6 million TEUs to 30 million TEUs. In

[82] Lee & Lam, 2015, pp. 118 ff.; Port of Singapore Authority [2], n.d.
[83] Tuck Yew, 2012
[84] Port of Singapore Authority [3], n.d.
[85] Maritime and Port Authority of Singapore, n.d., p. 4
[86] Goh, et al., 2008, p. 363; cf. Lee & Lam, 2015, p. 121
[87] Möller, 2013, p. 240
[88] Economic and Social Commission for Asia and the Pacific, 2005, pp. 43 f.

year 2009, the financial crisis[89] hit the world trade and the total turnover number decreased by 43 million tons, whereas the container turnover decreased by 4 million TEUs. From that time onwards, the numbers steadily rose, reaching their peaks in 2014 with 581 million tons total turnover and 34 million TEUs of container turnover. However, both numbers decreased again in 2015. The total turnover dropped by 6 million tons and the container turnover had to record a decrease by 3 million TEUs. This decline can be explained by a general decline of cargo volumes being transported between Europe and Asia as well as an increase in the number of direct sailings because of lower bunker prices.[90]

Figure 4: Total Cargo Turnover and Container Turnover Developments of the PoS from 2001 to 2015



Source: Based on The Maritime and Port Authority of Singapore, 2002; Ministry of Transport, 2003; The Maritime and Port Authority of Singapore, 2008; The World Bank, n.d.; The Maritime and Port Authority of Singapore [1], 2015; The Maritime and Port Authority of Singapore, 2016

It is predicted that especially transshipment ports will benefit from the continuous growth of vessel sizes. Therefore, future cargo throughput developments will be rather positive for the PoS.[91] However, due to increasing competition, the PoS experiences lower growth rates. Competitor ports like Shenzhen (China), Tanjung Pelepas (Malaysia) and the Shanghai

[89] Biermann & Teuber, 2012, p. 7
[90] The Maritime and Port Authority of Singapore, 2016
[91] Economic and Social Commission for Asia and the Pacific, 2007, p. 56

International Port (China) are deep water ports and, hence, can handle even bigger container vessels.[92]

4.2.3 Two Projects in Focus: Pasir Panjang Terminal and Tuas Mega Port

The Pasir Panjang Terminal is currently the most modern terminal of the PoS.[93] Phase 1 and 2 were completed in 2010.[94] However, phase 3 and 4 are still under construction, offering advanced technologies in future and allowing the port to raise its capacity by half, to 50 million TEUs.[95] Construction works of both phases will be finished by 2017.[96]

In addition to these developments, Singapore's transport minister, Mr. Lui Tuck Yew, announced the consolidation of all container port activities at Tuas in October 2012, leading to increased economies of scale and higher efficiencies due to the elimination of inter-terminal transports. Construction works started in 2015 and the first berths will be ready for operation by around 2022. This action will increase the port's capacity to up to 65 million TEUs per year. Even more advanced technologies will ensure the handling of ever larger ships and the increasing number of containers. [97] With regard to these future developments, the Port Technology Research and Development Program was launched in April 2011, studying, inter alia, techniques and technologies for optimization purposes, automated container port systems like Automated Guided Vehicles (AGVs) as well as green port technologies.[98] In order to make better use of land scarcity, the future port might provide space above- and underground.[99]

[92] Goh, et al., 2008, p. 361; Shanghai International Port Group , n.d.
[93] Port of Singapore Authority [3], n.d.
[94] The Maritime and Port Authority of Singapore [1], 2012, p. 17
[95] Tuck Yew, 2012
[96] Tan, 2015, p. 1
[97] Tuck Yew, 2012; cf. The Maritime and Port Authority of Singapore [1], 2012, pp. 20 f.
[98] The Maritime and Port Authority of Singapore [2], 2012, p. 27; Tuck Yew, 2012
[99] The Maritime and Port Authority of Singapore [2], 2015, p. 33

5 Comparing the Measures of Digitalization of the Port of Hamburg and the Port of Singapore

5.1 Loading and Unloading on the Water Side

The quay cranes at the CTA are the most advanced ones at the PoH. They work half-automatically with two crane trolleys. The main crane trolley is operated by a driver. The driver lifts the containers from the vessel and places them on a working portal higher up. Lashers can now remove or affix the twistlocks and check the container's identification. Thereupon the other crane trolley takes the container and lowers it on an AGV.[100]

In Singapore, the Pasir Panjang Terminal, phases 1 and 2, are equipped with unmanned remote-controlled quay cranes. Six cranes can now be operated at the same time by one worker.[101] This likewise increases the safety of workers as well as the port's productivity.

5.2 Transport in Terminals

Different methods are used in the PoH in order to transport containers from container vessels to storage locations and the other way round. On the one hand, van carriers are used, whereas on the other hand, the task is performed by AGVs at the CTA.

Van carriers are not working automatically. However, the PoH realized an increasing productivity by the use of van carriers. From 2011 on, they were able to transport two 20-foot containers at the same time which requires certain software for planning and controlling.[102]

Ten AGVs perform the fully battery-electric automatic transport at the CTA. AGVs operate on a delimited area which contains more than 19,000 transponders in the ground. Their signals allow for an AGV's positioning. Specifically developed software is looking for the fastest way through this area. When required, the AGVs drive to the battery change station

[100] Hamburger Hafen und Logistik AG [1], n.d.
[101] Maritime and Port Authority of Singapore, n.d., p. 4
[102] Hamburger Hafen und Logistik AG [2], n.d.

independently in order to change the battery.[103] Within five minutes, the battery charging station changes the 12 ton battery automatically. Besides more safety in the terminal through the use of automated transport, the use of exchangeable batteries leads to zero CO_2 emission of the AGVs.[104]

The software consists of several components. The two core components are “logistics simulation” and “energy demand optimization”. The first component’s task is to predict the logistics processes at the CTA. Based on this forecast, the overall power demand of the CTA and the battery-changing points are determined. For this, the terminal is abstracted into three components: Ship berthing area, transport area and container yard. Several data like the number of arriving ships, the number of containers to be handled, continuously monitoring and registration of power consumption of all processes, lighting, the power consumption of administration buildings and information regarding the hinterland connection are needed in order to create an energy-forecast and to determine the times for battery exchange. The second component aims at optimizing the power demand. Different aims can be pursued like the avoidance of new load peaks or that batteries are mainly charged when renewable energy is highly available. Both the charging schedule and times of battery exchanges can be adjusted as long as the logistic processes are not negatively influenced.[105]

The PoS is also planning to introduce AGVs in order to increase port productivity and to reduce manpower. Prototypes were already developed. However, they are not running yet at the PoS since they are planned to feature at the future port in Tuas and at Pasir Panjang Terminal phases 3 and 4.[106]

[103] Hamburger Hafen und Logistik AG [1], n.d.
[104] Hamburger Hafen und Logistik AG [3], n.d.
[105] Ihle, et al., 2014, pp. 4 f.
[106] The Maritime and Port Authority of Singapore [1], 2012, pp. 15 ff.; Port of Singapore Authority, 2013, p. 15

5.3 Container Storage in Terminals

At the PoH, double rail mounted gantry cranes (DRMGs) and triple rail mounted gantry cranes (TRMGs) perform the storage of containers in block storages automatically. DRMGs consist of two cranes with different heights allowing for parallel working. TRMGs consist of two twin cranes using the same rails and a third, higher one, using different rails. Containers are stored based on information given by software. The storage area is then optimized in times of less container traffic. The pick-up of containers on land-side takes place by trucks or terminal-owned chassis. Workers at the control center use cameras and joysticks in order to place the containers on the vehicle.[107]

Pasir Panjang Terminal phase 3 and 4 in Singapore will be equipped with unmanned automated rail mounted gantry cranes as well. These will be operated by electricity supporting the aim of the PoS to be an environmentally sustainable port.[108] Furthermore, the automated rail mounted gantry cranes will include a laser-guided chassis alignment system and a container and prime mover recognition system.[109]

Crane operations at the Pasir Panjang terminal are supported by RCOC (Remote Crane Operations & Control). The terminal operation system sends a job order to an Overhead Bridge Crane (OHBC) which in turn sends a request to the Remote Crane Operation Control System which transmits the job order to a remote operator. "Real-time live video and data streaming of images from the OHBC cameras and data signals exchange between the OHBC and the operator's consoles to achieve similar quality of service as if the operators are physically on the OHBC executing the jobs" (Port of Singapore Authority [4], n.d.). This leads to higher productivity, less manpower needed as well as to more comfort for crane operators.[110]

[107] Hamburger Hafen und Logistik AG [1], n.d.; Klaws, et al., 20
[108] Port of Singapore Authority, 2012, p. 1
[109] Port of Singapore Authority, 2013, p. 15
[110] Port of Singapore Authority [4], n.d.

5.4 Hinterland Traffic and Related Processes

DIVA (Dynamic Traffic Volume Information System) is the first step towards a smart management of traffic at the PoH. It is a road information system that provides real-time traffic information to road users in the port area. The HPA works on DIVA since 2009 pursuing the aim to eliminate traffic interruptions as far as possible. The information is displayed on 16 enormous LED message boards at various points throughout the port area and can be checked on the internet.

All traffic information is gathered through “300 inductive traffic loops and 160 sensors installed at bridges and pillars [which] accurately register traffic volumes in the port: the number and type of vehicles as well as their speed” (Hamburg Port Authority, 2011, p. 20). In addition, Bluetooth sensors located throughout the port measure travel times of vehicles and “video cameras record the traffic density and send their high-resolution images directly to the traffic control centres of the police” (Hamburg Port Authority, 2011, p. 19) allowing for short reaction times to traffic jams and accidents.[111] The information will be encrypted and transmitted via fiber optic cables to the Port Road Management System where it will be merged into one system, called EVE (Effective depiction of the traffic situation), analyzed quickly and thereupon transmitted to the message boards in real time. However, EVE is not only used for DIVA. The results of the traffic situation determination are also available to other services. EVE’s aim is to ensure an efficient traffic management in general.[112] DIVA therefore provides information regarding waiting times, disruptions and consequently suggests alternative routes.[113] Furthermore, the boards also display information regarding the HHLA terminals and the current loading situation[114] as well as blocking times of the port’s movable bridges. Pointless waiting times are reduced, leading to improved traffic flows and processes in the PoH and, hence, to increased productivity. DIVA is therefore not only beneficial to hauliers,[115] but it is also advantageous to the environment since the traffic is kept moving wherefore less exhaust gas is produced.[116]

[111] Hamburg Port Authority, 2011, pp. 19 f.
[112] Hamburg Port Authority [2], n.d., pp. 5 ff.
[113] Hamburg Port Authority, 2011, p. 19
[114] Hamburg Port Authority [2], 2015, p. 16
[115] Hamburg Port Authority [2], 2012, pp. 11 ff.
[116] Hamburg Port Authority, 2011, p. 20

In order to improve rail management in Hamburg, TransPORT Rail Basic was introduced in June 2012 in the course of the IT project EVITA (Rail Traffic Information Operations System). It is one of the most modern railway management IT systems being utilized globally. In 2013, it completely replaced the former system HABIS (Port Railway Operating and Information System).[117] TransPORT Rail Basic is used for process optimization purposes leading to a more efficient port railway.[118] The "system provides infrastructure data to facilitate train scheduling as well as sequencing and booking of sidings and hence helps to optimise the ever more complex processes, reduce transit times and increase handling capacities" (Hamburg Port Authority [1], 2013, p. 5). The PoH is not only a transport hub, it is becoming an information hub as well since data of loading points, track capacity and private rail companies are integrated with each other and customized information is provided to the participants like local railway infrastructure companies, loading stations and train operating companies.[119] Interfaces between these parties and components are standardized and processes are characterized by a high degree of automation.[120] This allows for improved data exchange and communication which can be done also web-based via an online portal.[121] Furthermore, it features flexibility since "additional service modules or rail freight operators and logistics companies can be linked up at any time" (Hamburg Port Authority [2], 2013, p. 10).

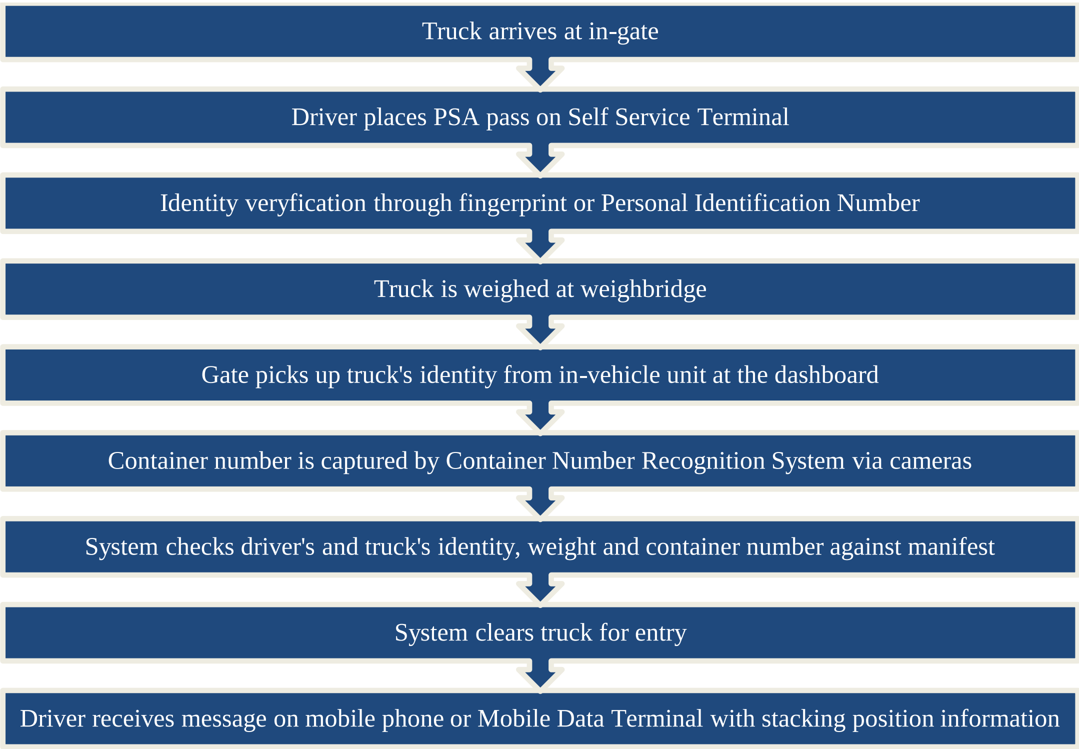
Moreover, the intelligent switch was introduced. Multi-sensor systems are installed at certain points of the port railway network. In order to predict the need for switch maintenance, these multi-sensor systems measure the energy needed for a switching process as well as data of railway crossing. This leads to a continuous reporting and, thus, more transparency of the condition of major railway points. The increased transparency in turn allows for enhanced planning of maintenance operations, less unplanned malfunctions as well as appropriate and preventive actions before disruptions occur.[122]

In May 2015, the first intelligent traffic light was presented by the HPA. These traffic lights aim at allowing a fast and secure traffic flows in the port area. Along with the reduction of traffic jams, the production of exhaust gas will be reduced. Special WLAN communication,

[117] Hamburg Port Authority, 2012, p. 52
[118] Hamburg Port Authority [2], 2012, p. 18
[119] Hamburg Port Authority [3] , 2015, p. 28
[120] Hamburg Port Authority [2], 2013, p. 10
[121] Hamburg Port Authority [1], 2015, p. 16
[122] Hamburg Port Authority [2], 2015, p. 34; Hamburg Port Authority [2], n.d., p. 6

the “Vehicle-to-X” (V2X) communication, enables a wireless communication between vehicles and infrastructure elements like traffic lights, traffic signs and constructions sites. If a convoy is registered by a smart traffic light, green phases can be adjusted, for example extended, so that no vehicle has to stop. Furthermore, RFID technology enables the recognition of endangered road users in the area of the traffic light. Alarm signals will be sent to approaching truck drivers via V2X in order to avoid accidents.[123]

Figure 5: Flow-Through Gate Process at the Port of Singapore



Source: Based on Port of Singapore Authority [4], n.d.

Since 2011, truck drivers are also able to clear their standard containers within 130 seconds at the PoH through the use of touchscreen-designed self-service terminals. Truckers need a valid trucker card and complete container data in order to perform the process by themselves. Self-service allows for shorter waiting times and generally faster clearance processes.[124]

[123] Hamburg Port Authority [4], 2015
[124] Hamburger Hafen und Logistik AG, 2011

The PoS uses a similar system. The Flow-Through Gate at the PoS is a completely automated system that allows for a quick container truck clearance. Arriving trucks will be identified by the system and the drivers receive instructions within 25 seconds accordingly. Figure No. 5 illustrates the Flow-Through Gate process. The Flow-Through Gate system was introduced in 1997 allowing for the average handling of around 8,000 trucks a day.[125]

5.5 Communication with Stakeholders

Communication with stakeholders takes place in different ways. First, SmartPORT Logistics is a cloud-based information and communication system. It consists of a web application as well as a mobile app, called SPL, via which port operators, hauliers and logistics companies can share all relevant data regarding traffic, infrastructure and logistics in real time. The app calculates arrival times and serves as route planner and navigation aid. Besides information access via mobile devices like tablets and smartphones, truck drivers can communicate directly with dispatchers and are able to look at their transport orders.

The app is beneficial to both drivers and dispatchers. The dispatcher is able to see the driver’s position in the port and can assign him or her tours accordingly. The driver avoids waiting times since he/she receives up-to-date traffic data.[126] In the near future, truck drivers will also receive information regarding parking space capacities of the car parks. The future parking space detection system will determine the occupancy of car parks participating at the smartAREA parking project. The gathered information can be directly communicated to the truck drivers and other traffic participants in the port area.

[125] Port of Singapore Authority [4], n.d.
[126] Hamburg Port Authority, 2015, p. 10

The technologies listed below will enable this system:

- “Vehicles will be counted and the type of vehicle recognised using an induction loop featuring correlated algorithm.
- Balancing of occupancy via evaluation of measured inflow and outflow at the induction loops.
- System calibrating using a verification camera with comprehensive occupancy detection” (Hamburg Port Authority [2], 2015, p. 35).

The future parking system in combination with the app will enable drivers to book parking lots in advance. This leads to increased utilization rates and higher economic efficiency of car parks, the reduction of traffic in search for a parking lot and therefore the reduction of environmental pollution.

In addition, the aim of the introduced Smart Maintenance project is to check the infrastructure of the PoH like roads, bridges and rail via mobile devices like tablets and smartphones. The devices communicate online with downstream IT systems, called backend systems. These systems process data which can be used for creating messages. This leads to more effective and efficient maintenance processes and enhances the quality of messages.[127]

Moreover, the Port River Information System Elbe (PRISE) was completely launched in March 2014. Since growing ship sizes lead to increasing planning and execution complexity, the IT system PRISE aims at optimizing the management of ship arrivals and departures at the PoH. It allows for faster information exchange among all parties since it merges all information from all parties which are involved in the handling process. The handling process includes, amongst others, terminals, pilots, tug boats, the HPA, ship owners and brokers, providing berth planning and berth booking data, status information regarding ship locations on the Elbe and water level predictions etc. Therefore, the PoH is able to plan ahead more precisely, react faster to short-term changes and to use its resources more efficient. By March 2014, no other port worldwide was using such a platform.[128]

The PoS uses a similar tool. PORTNET is the world’s first nation-wide B2B port community solution system. “It has provided the logistics industry with a single sign-on network portal. Through it, the Port of Singapore Authority (PSA) has connected shipping lines, hauliers,

[127] Hamburg Port Authority [2], n.d., pp. 8 ff.
[128] DAKOSY Datenkommunikationssystem AG, 2014

freight forwarders and government agencies, helping them to manage information better and synchronise their complex operational processes" (Port of Singapore Authority [4], n.d.). It has more than 9,500 users who cause around 220 million PORTNET transactions a year. Some of its functionalities encompass the management of transshipment processes, support of slot exchanges among the parties, performance monitoring and the integration of port documentations with processes and workflows of haulages. Furthermore, it serves as a documentation portal connecting shippers and shipping lines with each other.[129] In 2013, PORTNET Mobile was launched. Since then it is also possible to access its information via any mobile device.[130]

Furthermore, MARINET, a system that supports and provides various E-services for the maritime community of the PoS, is in use. It enables a faster clearance of shipping and port documents "and disseminate critical ship arrival and departure and other value-added shipping information to port users to enable them make informed decisions" (The Maritime and Port Authority of Singapore [2], n.d.).

TETRA (Terrestrial Trunked Radio) is a digital radio system used at all PSA terminals and belongs to Motorola's product range. This digital radio system ensures fast, reliable and clear communication in the terminals. It is a supporting tool that helps to manage processes more efficiently. It allows for a continuous information exchange among many users in order to take decisions faster and to coordinate movements of cargo and equipment in the terminal.[131] Furthermore, it is beneficial to the safety of workers. If an accident occurred, "crew member could easily activate the emergency button, alert the team on the same talk group channel, and notify the control room, bypassing whoever is ahead of him in the communication queue to reach the control centre" (Motorola Inc., 2006, p. 2).

Besides communication, which supports processes that are directly linked to port operations, there is also social media communication. Both ports are active in several social networks. Five social media platforms were taken into consideration, namely Facebook, Twitter, Instagram, YouTube and LinkedIn. Neither the PoH nor the PoS are active on Facebook. However, Twitter is used by both. The PoH counts 1740 followers (as by 2nd February 2016)

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[129] Port of Singapore Authority [4], n.d.
[130] Lee & Lam, 2015, p. 119
[131] Port Technology International, 2006, p. 18

and its “tweets” are welcoming ships arriving at the PoH.[132]The Maritime and Port Authority of Singapore (MPA) in comparison counts 995 followers (as by 2nd February 2016) on Twitter. It tweets every day, sometimes even more than once. Tweets are constantly accompanied by pictures and contain information and latest news of the PoS, information about special guests and also quizzes about the PoS.[133] Furthermore, the PoH can be also found on Instagram, whereas the PoS does not have an account on Instagram. The HPA as representative for the PoH counts 666 followers (as by 2nd February 2016) and shares mainly pictures of ships in the port with their community.[134] Both the PoH as well as the PoS are represented on YouTube. The HPA counts 1619 subscribers (as by 2nd February 2016) and a total number of 276 videos of different topics. Most of them approach general news, the smartPORT project and current as well as future developments.[135] By comparison, the MPA counts 116 subscribers (as by 2nd February 2016), shares different kinds of videos but not on a regular basis. 15 videos can be found on the channel of the MPA.[136] Both ports are active on LinkedIn. The HPA has 546 followers (as by 2nd February 2016)[137], whereas the MPA counts 9,639 followers (as by 2nd February 2016).[138]

5.6 Cross-Process Measures

TLS (Terminal Logistics and Controlling) is a control software which combines transshipment with storage, rail and road traffic at the CTA in Hamburg. The software was developed by the HHLA itself and is continuously being adjusted to new requirements. TLS controls the cranes and container carriers via radio data transmission. This allows for shorter driving distances, less empty runs as well as on-schedule handling of transportation orders with optimal utilization of resource capacities.[139]

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[132] Port of Hamburg [2], n.d.
[133] The Maritime and Port Authority of Singapore [3], n.d.
[134] Hamburg Port Authority [4], n.d.
[135] Hamburg Port Authority [5], n.d.
[136] The Maritime and Port Authority of Singapore [4], n.d.
[137] Hamburg Port Authority [6], n.d.
[138] The Maritime and Port Authority of Singapore, n.d.
[139] Hamburger Hafen und Logistik AG [1], n.d.

CITOS (Computer Integrated Terminal Operations System) is an Enterprise Resource Planning system. The system is used at the PoS in order to flexibly manage people and the port's equipment in real time. It directs the port operations through various systems: berthing system, ship planning system, yard planning system, resource allocation system, flow-through gate (see chapter 5.4) and reefer monitoring.[140] PORTNET (see chapter 5.5) and CITOS are seamlessly integrated with each other in order to optimize the efficiency of port logistics and container handling serve.[141]

Internet allows for general IT operations and information exchange between different parties. The PoH ensures high-speed data transmission through the use of WLAN and fiber optic cables.[142] Additionally, the PoH offers free WiFi internet access to all shipping crew members in the port area.[143] In Singapore, high-speed internet can be accessed throughout the port area on land as well as up to 15km at sea.[144] In 2009, the PoS introduced wireless broadband access to ships in the waters of the PoS.[145] Various base stations located along the shorelines of Singapore transmit WiMAX (Worldwide Interoperability for Microwave Access) signals wirelessly. Access is gained applying one of the three following options. Wireless internet can be accessed through either a USB dongle being plugged into an onboard computer, an external modem attached to a computer with which other computers can connect or an antenna being attached to the roof of the ship and which is then connected via cables with computers inside the ship.[146]

[140] Port of Singapore Authority [4], n.d.
[141] Kim, Kap Hwan; Lee, Hoon, 2015, pp. 67 f.
[142] Baekelmans, n.d.
[143] Crew Center, n.d.
[144] Swift, 2011, p. 48
[145] The Maritime and Port Authority of Singapore, 2010, p. 22
[146] Swift, 2011, p. 48

5.7 Safety in Water and on Land

The Vessel Traffic Service Center in Hamburg is one of the most advanced surveillance centers worldwide. In January 2012, the refurbishment of the center started. It is equipped with the most modern technical tools. Navigational safety is ensured through the use of radar, video technology, Automatic Identification System, data sharing networks, very high frequency radio communication and the so-called “Port Monitor”.[147] The Port Monitor is a combination of software and visualization tool. Data of different measuring and communication systems throughout the port are gathered, evaluated and, finally, displayed in a clear graphical form. It supplies all data which are needed in order to plan, secure and control shipping traffic in the PoH. This includes information about vessel positions, water levels, berths, bridge heights and widths as well as updated information of, for instance, construction sites and diving missions. The Port Monitor aims at providing a complete overview of the current traffic situation on the port’s waterways. Furthermore, since 2013, it is also accessible via mobile devices. The Mobile Port Monitor allows users to enter data directly on the ground which is then transmitted to the vessel traffic service center in real time. In future, all modes of transport will be connected with each other, including road and rail.[148]

In order to further enhance safety and security in the PoH, the Smart Tag was developed. Smart Tag is a Global Positioning System (GPS). The sensor can be attached to or installed in an object. If activated, the sensor sends its position and its ID to a central system. The system collects all information which can be processed further. This allows for the localization of valuable objects, the creation of movement profiles of, for example, shunting locomotives. Furthermore, they can be also used in order to enable a more efficient vehicle fleet management or for tracking purposes in the situation of a disaster.

Besides GPS sensors, additional sensors can be integrated which enable the measurement of temperature, wind forces and directions and air pollution. During the pilot run, a sensor will be installed at a road work traffic sign. If the tracking of an object is not necessary any longer, the sensor can be de-installed and attached to another object.

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[147] International Association of Ports and Harbors, 2014

[148] Hamburg Port Authority, 2015, p. 12; (Hamburg Port Authority [3] , 2015, p. 11; Hamburg Port Authority [2], 2015, p. 17

Furthermore, a smart light mechanism was introduced in Hamburg in order to ensure safety for pedestrians and cyclists in the port area. The light is controlled according to lighting conditions and objects measured by sensors in the lighting area.[149]

In 2011, a new Port Operations Control Centre was developed and built at the PoS. The new Vessel Traffic Information System of the PoH ensures navigational safety and safe movements of vessels in the waters of the PoS. It merges the information from various tracking systems like radar, the Harbor Transponder System, the Automatic Identification System and images from closed-circuit television cameras. This allows for the tracking of 10,000 ships at the same time.[150] It is said to be “a state of the art next generation Vessel Traffic Information System” (The Maritime and Port Authority of Singapore, 2011, p. 24).

In terms of the Automatic Identification System, vessels in the PoS can be installed with a transponder approved by the MPA. The carrying of the transponders allows ships and their movements to be visible to other ships nearby ensuring safe navigation.[151]

[149] Hamburg Port Authority [2], n.d., pp. 7 ff.
[150] The Maritime and Port Authority of Singapore [2], 2012, p. 19
[151] The Maritime and Port Authority of Singapore, 2011, p. 31

6 Defining a Digital Status of the Port of Hamburg and the Port of Singapore

6.1 Presentation of the Evaluation Method

In order to better evaluate the digitalization progress of the PoH and the PoS, the measures will be evaluated based on a scale. The evaluation also includes the measures which have not yet been introduced but will be implemented in the near future. Each measure will be assigned to one of the enabler technologies of the four levers of digitalization, namely automation, digital customer access, connectivity and digital data which were explained in chapter 2.2.

Table 1: Ordinal Scale for the Evaluation of the Degree of Digitalization

Stage/Points	1	2	3	4	5
Degree of Digitalization	Very low	Low	Moderate	High	Very high

Source: Own Creation

The evaluation is made using a five-stage ordinal scale. Each stage simultaneously expresses the number of points which can be assigned to a port. In the end, the sum of the point scores allows for a direct comparison of the PoH and the PoS and for a final statement which port is more advanced regarding digitalization.

6.2 Analyzing and Evaluating the Digital Progress of the Port of Hamburg and the Port of Singapore

6.2.1 Automation

At the PoH, the process of loading and unloading vessels is half-automated through the operation of two crane trolleys. A driver still has to operate the main crane trolley sitting in a cabin at the top of the crane. However, cranes at the PoS will be soon unmanned and operated remote-controlled. Singapore is thus a step ahead of Hamburg (see chapter 5.1).

The AGVs at the PoH allow for automated transportation of containers in the port. Furthermore, the battery exchange of the AGVs is an automated process. AGVs will be implemented soon at the PoS as well allowing for automatic transport (see chapter 5.2).

Containers in both ports are stored automatically through the operation of rail mounted gantry cranes. These are controlled by specific software allowing for a structured and organized storing procedure (see chapter 5.3).

In addition, the check-in of truck drivers at the terminals takes place automatically (see chapter 5.4).

Automation is an important issue in order to increase productivity and safety as well as to reduce the manpower needed. Both the PoH as well as the PoS have already widely implemented robotics in order to increase the level of automation. There is still the potential for improvements in both ports since not all processes have been automated yet and there are still humans supporting processes directly in the port area, like lashers removing twistlocks and van carrier drivers. There is still potential to increase the number of processes being automated. The PoS seems to be a little more ahead since quay cranes will be operated remote-controlled soon. However, despite this fact, both ports show a very high degree of automation. The PoH is slightly behind the PoS but its automation progress is still very high. Additive manufacturing as enabler technology of digital transformation will not be considered for the evaluation since manufacturing is not a purpose of ports. Therefore, both ports will be assigned a rating of 5 in terms of the degree of digitalization and automation.

6.2.2 Digital Customer Access

Apps are mainly used in order to facilitate information flow and to ensure direct and fast communication for more safety in real time like SPL and the Port Monitor (see chapter 5.5) which is also accessible via mobile devices at the PoH. Furthermore, Smart Maintenance is utilized via mobile devices (see chapter 5.5) and Smart Traffic Lights are able to send alarm signals directly to truck drivers (see chapter 5.4).

PORTNET, Singapore's counterpart to the SPL, is also accessible via any mobile device and allows for direct B2B communication. In addition, after the check-in process at the terminal, the truck driver receives messages on his/her mobile device with further instructions (see chapter 5.4).

Mobile devices allow for communication mobility and the ongoing development of software applications facilitates interaction among, for example, customers, suppliers and employees along the value chain of organizations whenever wanted and needed.[152] The potential in this trend was recognized and is used by both ports. The PoH and the PoS ensure an improved performance in several port areas through the use of mobile devices and apps. However, the PoH offers more apps and features and therefore uses this technology more intensively than the PoS. The PoH is assigned a rating of 5 in terms of the degree of digitalization and mobile apps. The PoS is on its way from a high to a very high intensity regarding the disposal of apps. However, since it is not yet on the same level as the PoH, the PoS is rated with 4 points.

Both ports are active on social media platforms or rather in social networks. However, the PoH often shows more followers and more activity than the PoS, whereby the quality of posts/tweets is not always on a high level. Nevertheless, both ports could make even more use of the potential, which is implied by social media platforms and networks (see chapter 5.4). Therefore, both ports will be assigned a rating of 3 in terms of the degree of digitalization and social networks.

[152] Cray, 2014, p. 1

Since the usage of apps is evaluated with a higher importance for ports than the usage of social networks, the weighting for the final points assigned will be as follows: 75 percent weighting for the disposal and usage of apps and 25 percent for the activity and usage of social networks.

This results in 4.5 points for the PoH and 3.75 points in terms of the degree of digitalization and digital customer access.

6.2.3 Connectivity

Both ports use cloud computing in order to facilitate data and information exchange between a number of different parties. Major examples for the PoH are PRISE, SPL (see chapter 5.5) and TransPORT Rail Basic (see chapter 5.4). PORTNET, as the world's first nation-wide B2B port community solution system on the other hand, is a major example for the PoS and cloud computing (see chapter 5.5). These systems make a significant contribution to both port's process efficiency.

Furthermore, it can be noted that both ports offer fast broadband internet connection on land and at sea. Information is mainly transmitted via WLAN and fiber glass cables (see chapter 5.6). This allows not only for high-speed data exchange and communication between humans but also between things, for example, in the case of Hamburg via the special WLAN communication V2X (see chapter 5.4).

In summary, both ports show high level cloud computing and broadband internet advancement. Therefore, both ports will be assigned a 5 in terms of cloud computing and broadband internet connections. Both components will be weighted equally in the evaluation with 50 percent each. This leads to the final evaluation of 5 points for the PoH and 5 points for the PoS in terms of the degree of digitalization and connectivity.

6.2.4 Digital Data

Digital data is a fundamental component of port's operations nowadays. The IoT has become an important technology at the PoH. Sensors allow for additional information gathering. At the PoH, different kinds of sensors are in use measuring, for example, traffic volumes and times, energy flows (see chapter 5.4), temperature, wind forces and directions as well as air pollution (see chapter 5.7). Furthermore, transponders in the ground allow AGVs to move containers in the port automatically with no need for human intervention (see chapter 5.2). In addition, Smart Tag sensors allow for flexible attachment to things (see chapter 5.7). The information being gathered by sensors and other tools in the port leads to a high amount of data and information that has to be organized, controlled and communicated by applications and software like DIVA and SPL (see chapter 5.4 and 5.5). Furthermore, various external parties like hauliers and logistics companies send and require digital data for their operations, leading to a further increase of data amounts which have to be processed and controlled (see chapter 5.5).

By comparison, data exchange between software, human and machines allows for efficient processes like the interaction between RCOC and cranes operating at the PoS (see chapter 5.3). Furthermore, AGVs for automatic container transport in terminals will be introduced soon (see chapter 5.2). Moreover, the interaction of cameras, machines, software and humans will soon enable remote-controlled quay cranes (see chapter 5.1). However, derived from the previous analysis, it can be assumed that sensors do not play such an important role as they do at the PoH yet. Therefore, the IoT has not yet arrived to the same extent at the PoS as at the PoH. Despite this, the PoS has developed and uses highly advanced software tools like PORTNET and CITOS (see chapter 5.6) in order to deal with the big amount of data being gathered throughout port operations.

However, wearables as enabler technology of digital data have not yet been introduced, neither at the PoS nor the PoH.

The final points of "digital data" being awarded to both ports consist of three parts: the evaluation of IoT, big data and wearables. All components will be weighted equally. Due to the advancement of the PoH regarding IoT, the PoH will be assigned a rating of 5. Since the PoS is not so far advanced yet, it will be assigned 4 points in terms of IoT. However, both ports show very good progress in terms of big data in different aspects including data collection, exchange, organization and communication. The software and tools used by both ports can be described as far advanced leading to the evaluation of 5 points each. However, both the PoH and the PoS show a low performance regarding wearables. Therefore, both will be assigned a rating of 1 in terms of wearables.

The points awarded lead to the final evaluation of 3.7 points rounded for the PoH and 3.3 points rounded for the PoS in terms of the degree of digitalization and digital data.

6.3 Result and Recommendations for Future Developments

Table 2 shows the points assigned to each of both ports by enabler technology of digital transformation, the weighting of each enabler technology and the sum of all points. Furthermore, the evaluations which do not meet the maximum points achievable are encircled in red.

Table 2: Evaluation of the PoH and the PoS in Terms of Digital Transformation

Lever of Digital Tranformation	Enabler Technology	Weighting	PoH Points	PoS Points	PoH Final Points	PoS Final Points
Automation	Robotics	1	5	5	5.00	5.00
	Additive Manufacturing	/	/	/		
Digital Customer Access	Mobile Internet/Apps	3/4	5	4	4.50	3.75
	Social Networks	1/4	3	3		
Connectivity	Broadband	1/2	5	5	5.00	5.00
	Cloud Computing	1/2	5	5		
Digital Data	Wearables	1/3	1	1	3.7	3.3
	Big Data	1/3	5	5		
	IoT	1/3	5	4		
				Sum	**18.2**	**17.1**

Source: Own Table based on the Analysis in Chapter 6.2

The result is that the PoH receives a total number of 18.2 points and the PoS a total number of 17.1 points. This shows that the PoH is more advanced in terms of digital transformation than the PoS. However, both ports do not exploit the maximum potential of digitalization since the highest rating is 20 points and neither of the two ports achieved this score. Therefore, recommendations for future digital developments of both ports will be given in the following section.

The PoS shows a lower performance in the development and usage of apps than the PoH. However, mobile devices and apps are already in the focus of attention. In order to further facilitate and improve operations at the PoS, the inclusion of portable devices in port's operations could be extended. The PoH successfully implemented the app "Mobile Port Monitor" which allows an even faster communication of actions on the waterways of Hamburg. As planned, all different kinds of transport modes will be included in future (see chapter 5.7). The PoS could also offer its Vessel Traffic Information System as an app for even more efficient port processes.

Furthermore, both ports show a moderate performance regarding the usage of social network platforms. There are several options for the PoH and the PoS. First, they can extend the number of social networks in which they are active in order to reach a wider range of stakeholders. Both ports could join the social network Facebook. Second, it is also possible to increase the number of posts and tweets in order to establish deeper connections with stakeholders. The PoH could increase the number of photos being shared on Instagram, whereas the PoS could increase the number and frequency of videos being shared on YouTube. Third, it is not only the quantity of posts and tweets that matters but also the quality of posts. The PoH tweets regularly on Twitter. However, the shared content gives only information about arriving ships at the PoH. An improvement could be the sharing of information regarding innovation and new technologies being implemented at the port, current projects and their developments or information concerning people working at the PoH in order to give tweets a little more personality. Moreover, the focus of ports should be also on addressing politicians with social network activity. It is more difficult for ports to reach and influence political stakeholders and to determine awareness of them. This is indispensable when it comes to, for example, providing funds for the port or its infrastructure.[153]

The PoH as well as the PoS show a poor performance in the usage of wearables. Wearables could further facilitate work and make work more secure at both ports. Smartwatches could give information about workers' positions through GPS in case of emergency. Furthermore, information could be transmitted and instructions, like where to load or unload the container, could be read out loud to truck drivers ensuring higher safety since no messages have to be read on the smartphone. Another possibility is the usage of data glasses which provide workers directly with additional information on the screen. This reduces the time of

[153] Mercator Media Ltd., 2010

information transmission and communication and could lead to more efficient processes. It is conceivable that these glasses will be deployed in the process of loading and unloading vessels in future.

The PoS is slightly behind the PoH regarding IoT. Especially sensors play an important role in terms of IoT. The PoH uses various sensors in order to gather and analyze data and to act accordingly. The usage of sensors and transponders could be further extended at the PoS in order to increase its performance. Flexible sensors, like the Smart Tag at the PoH, could be also introduced at the PoS.

It is very important for both ports to keep an eye on future trends and their developments. Whereas the PoH already focuses a lot on hinterland developments and how processes concerning this part of the supply chain can be improved, the PoS focuses mainly on terminal developments. Although only 15 percent (see chapter 4.2.1) of arriving cargo is further transported by truck, this still makes a couple of million TEUs and will even make more TEUs in regards to increasing ship sizes and increasing amounts of cargo being transported in future. This already leads to port road congestion in Singapore.[154] Therefore, the PoS should not disregard the process of cargo transportation to the hinterland and should try to minimize congestion and to increase the port's productivity. The processes which deal with hinterland transportation might be improved and therefore become more efficient through digital measures being implemented at the PoS as they were at the PoH (see chapter 5.4).

As mentioned in chapter 3.1, it is of crucial importance to ports to keep productivity high in order to stay competitive. In order not to lose competitive advantages, it is important for both ports to pay attention to competing ports and their (digital) developments and to keep on going with their digitalization. Furthermore, despite fierce competition among ports, they can support and inspire each other. In the case of the PoH and the PoS, the PoS could learn a lot from the PoH regarding the digital transformation of its hinterland. The PoH, on the other hand, could receive inspiration from the PoS regarding remote-controlled quay cranes.

However, the focus should be not only on other ports but also on other industries and their digital developments. The collaboration with other industries could lead to new views and inspiration for own developments. Especially the travel and hospitality, the telecommunication and the high technology industry show a high level of digital intensity,

[154] The Maritime and Port Authority of Singapore [2], 2015, p. 34

meaning the intensity of creating initiatives through the use of new technologies.[155] Through more intensive collaboration with companies operating in these fields, the degree of digitalization, and therefore the digital transformation of the ports, could progress further. Furthermore, the automotive industry has made major progress in terms of digital transformation in the past decades. Therefore, the observation of the automotive industry, if not a collaboration with companies operating in this field, should also be considered.

[155] Westerman, et al., 2012, pp. 3 ff.

7 Conclusion

7.1 Summary

The current third economic revolution urges organizations to entirely digitalize. This implies that the use of technology will be increased in order to enhance organizational performance. The digital transformation takes effect via four levers, namely automation, digital customer access, connectivity and digital data. Each lever can be assigned two or more enabler technologies. Enablers of automation are robotics and additive manufacturing. Digital customer access' enabler technologies are mobile internet/apps and social networks, whereas connectivity comprises broadband and cloud computing as enabler technologies. Wearables, big data and the IoT make the enabler technologies of digital data.

Ports worldwide have to face a various number of challenges. The PoH and the PoS took numerous digital measures in order to cope with these challenges and to remain an attractive transshipment hub and actor in supply chains. The implemented measures were analyzed and evaluated with the aim of determining a state of progress regarding digital transformation of both ports.

The result shows that both ports are far advanced in terms of digitalization. However, the PoH is slightly more advanced than the PoS. Nevertheless, both ports show potential for digital improvements. They have to catch up especially in terms of social network activity and the application of wearables, whereas the PoS should also focus on the use of apps and the "Internet of Things". In addition, it is recommended to both ports to always keep an eye on the development of competing ports and to increase the level of collaboration with them as well as with organizations of highly digitalized industries in order to get suggestions for further digitalization measures and the improvement of already implemented ones.

7.2 Critical Acclaim

The digitalization is rather an ongoing-process than a state. This leads to the effect that in the moment something has been written down, it might be already outdated and does not comply with the latest findings. This thesis only focuses on digitalization aspects in order to face current and future challenges affecting ports. It has to be considered that there are also other measures and strategies which coexist with the already implemented digitalization measures in order to successfully deal with these challenges. Moreover, only main digitalization measures by both ports were mentioned. Furthermore, the evaluation of the implemented digitalization measures and the final evaluation of the digitalization progress is rather a subjective evaluation than an objective one. Finally, it has to be mentioned that the recommendations listed in chapter 6.3 are only possibilities how to further enhance the digitalization of both ports. However, it requires a complex and profound analysis in order to figure out the measures which suit each port best which is beyond the scope of this thesis.

7.3 Outlook

As digital transformation is a process, it will continue to proceed leading to even more digitalized ports in future. Due to the increasing number of ever larger container vessels, competition between ports will get more intense urging them to continuously work on efficiency improvements by the implementation and enhancement of digital measures. This may lead to only a few intensively digitalized major ports handling the major share of global maritime trade in future and to increased collaboration across industries in order to tap unused potentials. However, ships will not grow infinitely, but only up to sizes which make economic sense and which can be handled at important hubs. It would not make sense to enlarge them to a size which can be only handled by one or two ports worldwide. Furthermore, ports are becoming steadily more environmentally responsible and will further increase the use of green, ecologically friendly technologies. In addition, innovative technologies and autonomous machines will increasingly take over the work which is currently performed by human workers. This further enhances safety in port operations on the one hand but compels workers to change their profession on the other hand. Only a couple of workers will be needed in order to control machines and processes and, perhaps, to intervene in case something is not working properly and as planned resulting in deserted ports in which everything seems to be moved by an invisible hand.

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Appendix

Table of Contents

A1: Broadband Technologies and Their Functionalities

	Broadband Technology	Functionality
WITH CABLE	DSL	DSL (Digital Subscriber Line) is a broadband connection which use already existing telephone lines made of copper. It is based on the concept that connection lines are not fully used by voice transmissions. Free capacities are used for digital data transmission. A so-called “splitter” is needed for the division of voice- and data signals as well as a DSL modem. A router enables the connection of more than one computer.
	Glass fiber	Long and thin fibers which are made of quartz glass. Data will be coded as light signals and sent through optic fibers. Compared to copper cables, data can be transmitted significantly faster and with lower losses.
	TV cable	Offers broadband connection via copper coaxial cable via an existing TV cable network. This technology shows higher efficiency than DSL. The data transmission standard DOCSIS (Data Over Cable Service Interface Specification) determines modulation methods, frequencies and interfaces, which ensure the operation of a bidirectional coaxial cable network, which allows for data transmission. Currently a download rate of more than 100 Mbits/s can be achieved. In order to send and receive data, a particular cable modem is needed. The connection takes place at the multimedia outlet for cable TV.
WIRELESS	Satellite	Enables broadband access via geostationary satellites which are located 38,800 km above the earth’s surface above the equator. In order to use this connection, a satellite dish is needed. This technology provides transmission rates of 18 Mbits/s when downloading and 6 Mbits/s when uploading data.
	UMTS/ HSPA/LTE	UMTS (Universal Mobile Telecommunications System) has established itself as mobile broadband technology. It provides transmission rates of 384 Kbits/s when downloading and 64 Kbits/s when uploading data. However, the transmission rate decreases when either the distance from the radio mast or the number of users in the radio cell is increasing. HSPA (High Speed Packet Access) and LTE (Long Term Evolution) are enhancements of UMTS. With HSPA the maximum download rate of 42.2 Mbits/s and the maximum upload rate of 5.8 Mbits/s can be achieved. LTE allows for transmission rates of up to 100 Mbits/s. All connections can be used with mobile devices. They always seek and connect to the fastest connection which is available.
	WLAN	WLAN (Wireless Local Area Network) enables a local, wireless connection to the internet via radio. It is, as a rule, used in apartments and buildings. Antennas create small radio networks, so-called “hotspots”, with a radius of approximately 100 meters. The maximum transmission rate is 300 Mbits/s. It is possible to connect to WLAN with mobile devices as well as stationary computers; however, a WLAN-card is needed. Other devices like printers and scanners can also connect to and transmit data via a WLAN connection.

Source: Based on Bundesministerium für Verkehr und digitale Infrastruktur, n.d.

A2: Calculation of Future Fleet Size by Vessel Size

Vessel Capacity in TEU	Current Fleet Size in million TEU	Orderbook Fleet Size in million TEU	Future Fleet Size in million TEU	Current Fleet Size (19.8 million TEU)	Orderbook Fleet Size (4.2 million TEU)	Future Fleet Size (24 million TEU*)
100 - 2,999	3.96	0.42	4.38	20%	10%	18%
3,000 - 5,099	4.356	0.084	4.44	22%	2%	19%
5,100 - 9,999	7.128	0.504	7.632	36%	12%	32%
10,000 - 13,299	2.178	0.84	3.018	11%	20%	13%
13,300 - 17,999	1.584	0.84	2.424	8%	20%	10%
≥ 18,000	0.594	1.512	2.106	3%	36%	9%
Sum	19.8	4.2	24			

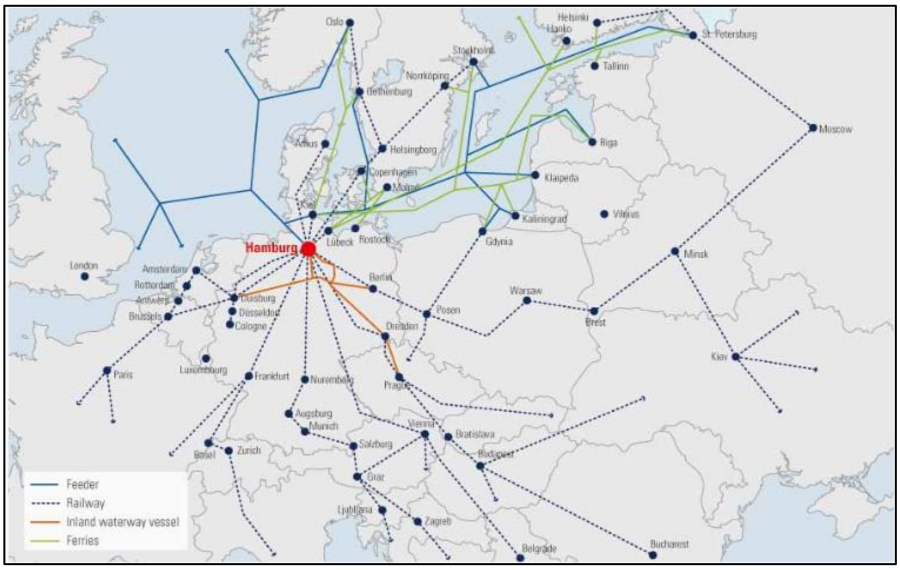
Source: Own Calculation Based on Schmidt, 2015, p. 22

A3: Main Trading Partners of the PoH

Rank			Container (in 1,000 TEU) jan. - dec.			
2014	2013	Trade partner	2013	2014	Change	in %
1	1	China (incl. Hong Kor	2,705	2,969	264	9.8
2	2	Russia	718	662	-56	-7.8
3	3	Singapore	547	533	-14	-2.6
4	8	Poland	322	395	73	22.7
5	4	South Korea	371	367	-4	-1.1
6	6	Finland	350	366	16	4.6
7	7	Sweden	350	326	-24	-6.9
8	5	USA	364	325	-39	-10.7
9	9	Malaysia	234	265	31	13.2
10	10	India	202	232	30	14.9
		Total	**6,163**	**6,440**	**277**	**4.5**

Source: Port of Hamburg Marketing, 2015, p. 36

A4: Hinterland Connections of the PoH



Source: Hamburg Port Authority [1], 2012, p. 12

Erklärungen

Eidesstattliche Erklärung

Hiermit erkläre ich, Janine Härtel, an Eides statt, dass ich die vorliegende Arbeit ohne fremde Hilfe selbstständig verfasst und nur die angegebenen Quellen und Hilfsmittel benutzt habe. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen sind unter Angabe der Quelle kenntlich gemacht.

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Hamburg, den 23. Februar 2016 ______________________________

(Janine Härtel)