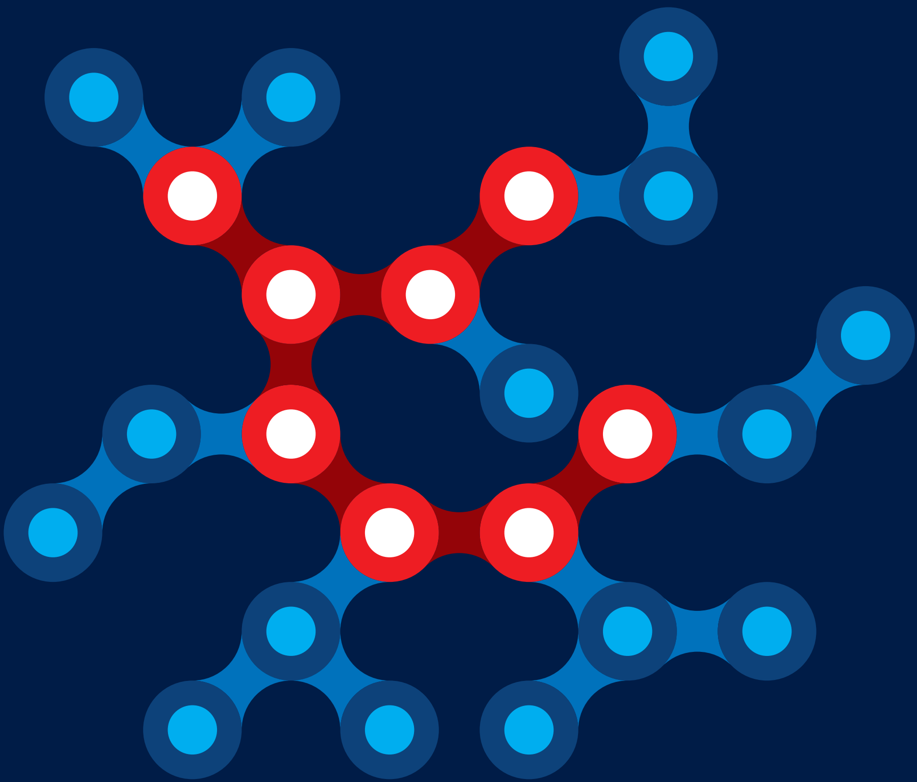
First Ideas

Digitalization of Seaports



First Ideas

Digitalization of Seaports

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1. INTRODUCTION AND MOTIVATION

INTRODUCTION

Supply chains have changed over the past decades, caused by the global division of labor, ever decreasing logistics costs, and the materialization of new markets. BRIC countries have continued to increase their significance for worldwide trade. For example, Asia has become the most important manufacturing location worldwide, Eastern Europe has entered the market economy, and the service industry in Europe and North America has grown substantially. Manufacturing emerges in additional locations or even returns to the developed economies.

The rise in total trade volumes, and subsequently in port volumes has posed a number of challenges towards industry participants. While world trade will continue to grow at lower rates, the global pattern of goods flow is likely to change. As part of maritime logistics, Port Authorities must make continuous progress in the competitive international environment. Digitalization and the associated changes to the flow of goods introduce new challenges to the industry.

Now is the time to redefine the world of maritime logistics to find solutions for present and future challenges. The traditional role of ports as part of the supply chain needs to be reevaluated. Port Authorities must scrutinize the performance of their ports and increase efficiency in port operations.

Increasing competition, the availability of new shipping routes, and new competitors in the logistics industry have a noticeable influence on Port Authorities. This is why the performance of ports as hubs in the global multimodal supply chains urgently needs to be optimized.

Maritime logistics actors need to actively take part in redesigning an optimal flow of goods. Information technology is the base, and digitalization in logistics is the key to success. Software, hardware and the worldwide connection are the tools for any kind of business. Connectivity enables process optimization and

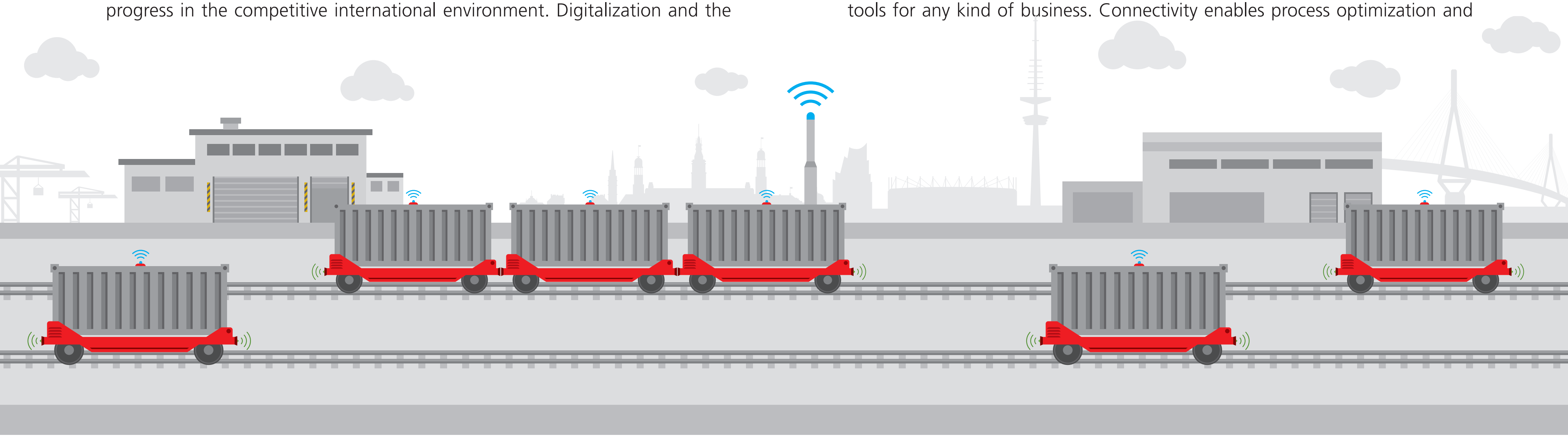


FIGURE 2: VISION OF SMART FREIGHT IN RAILWAY TRANSPORTATION

the development of new business models. And for that reason, it is crucially important to assess information technology from a maritime logistics' point of view. An important field of application is seaports and their connections to other ports as well as hinterland regions.

This booklet aims to highlight the tremendous opportunities that digitalization brings to maritime logistics. To take the opportunities, the booklet describes a network of Smart Ports, which is a global value-adding system of ports. The booklet gives the ports of the network an idea of how value co-creation can work and how the participating ports can benefit from each other. The focus of this booklet is on information technology only, other aspects like policy issues or staff exchange are not addressed.

The underlying idea is an informal network of Smart Ports willing to collaborate, fully taking into account the ports' independence. Through digitalization, the network is realized as an IT-framework without a central platform or authority. The network of interconnected Smart Ports aims to optimize maritime logistics by sharing good practices concerning innovative solutions within the network. The creation and sharing of knowledge about the possibilities offered by digitalization will result in a competitive advantage for the members.

MOTIVATION

The large world ports are complex ecosystems, where different actors must collaborate to maximize the supply chain's efficiency. Port Authorities play an increasingly active role. They optimize processes and operations in ports by

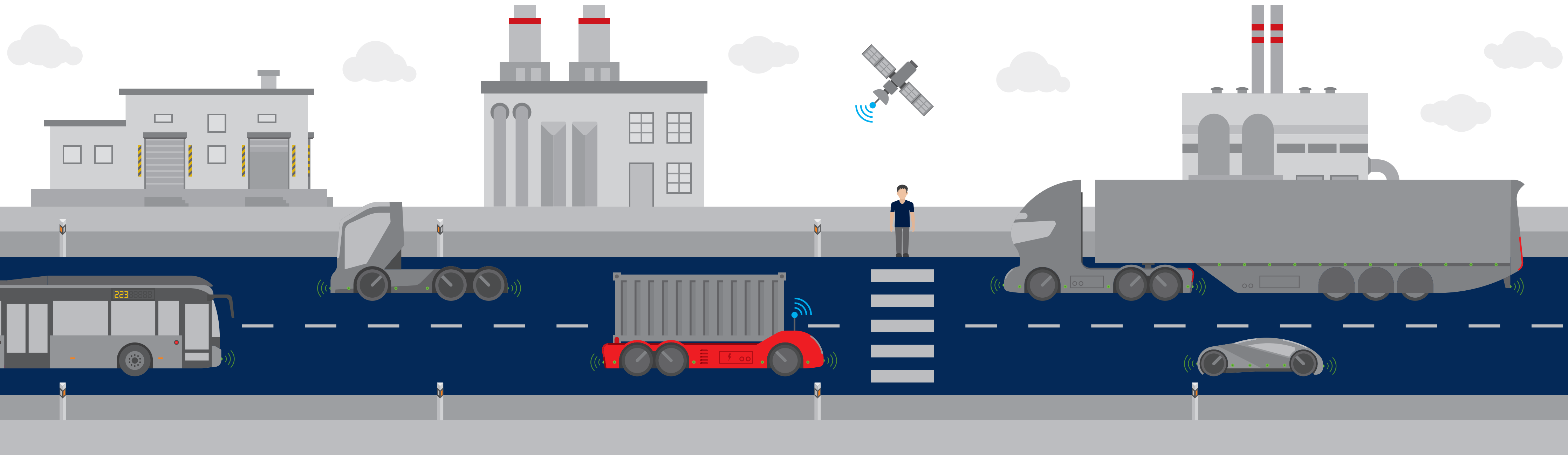


FIGURE 3: VISION OF AUTONOMOUS CONTAINER TAXIS FOR MOVEMENTS BETWEEN TERMINALS

coordinating all aspects of port operations, including the vessel approaching the port, the handling of the load unit, or cargo within the port, and even the transport to the hinterland destination, and vice versa. Port Authorities have the potential to significantly increase efficiency, security, and environmental sustainability in their port.

For example, the Hamburg Port Authority (HPA) has facilitated sustainable growth and a better utilization of resources for its customers while minimizing environmental impacts through its smartPORT concept. As part of the smartPORT concept, smartPORT logistics stands for intelligent solutions for an improved flow of traffic and goods in the Port of Hamburg, focusing on infrastructure deployment and considering both economic and ecologic aspects.

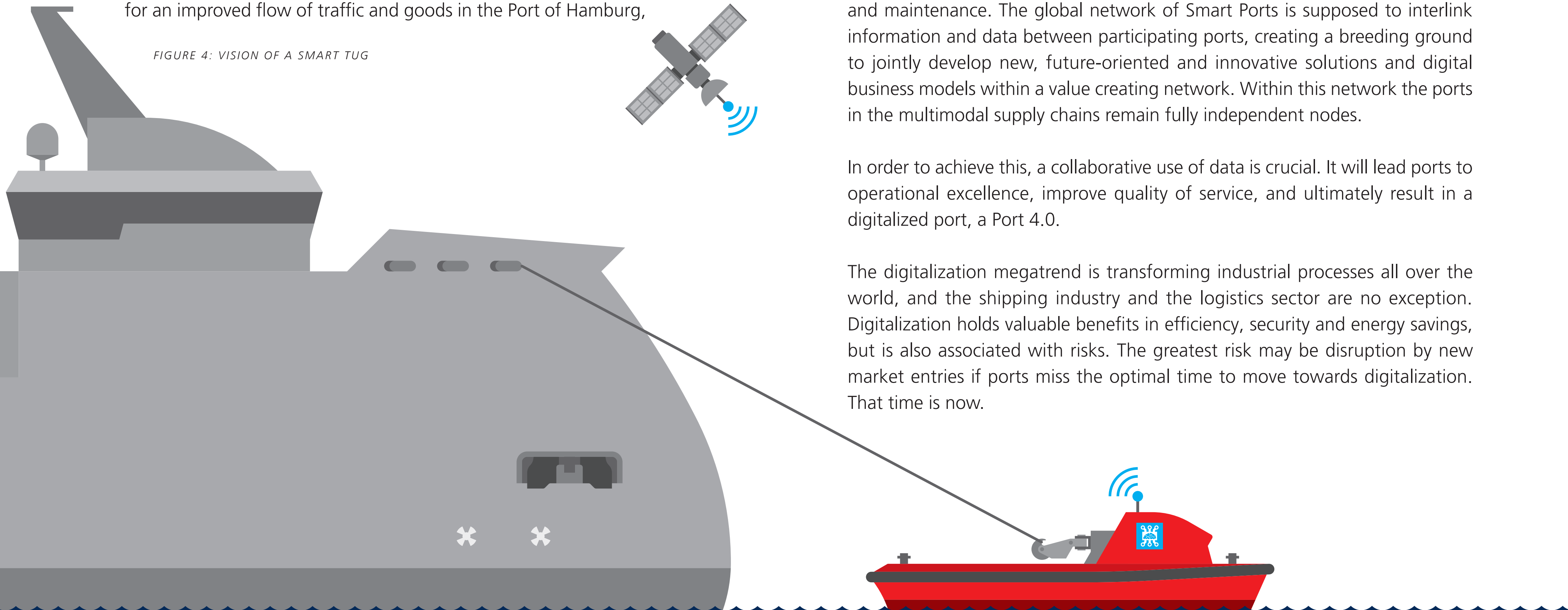


FIGURE 4: VISION OF A SMART TUG

With smartPORT energy, another component of the concept, HPA induces the deployment of renewable energy sources in the Port of Hamburg. Additionally, HPA encourages sustainable mobility. smartPORT energy reduces emissions, the dependency on fossil energy sources and saves costs.

Today, in a time of global networking, HPA continues its strategy for the digitalization of the Port of Hamburg – for example in areas like cruise shipping and maintenance. The global network of Smart Ports is supposed to interlink information and data between participating ports, creating a breeding ground to jointly develop new, future-oriented and innovative solutions and digital business models within a value creating network. Within this network the ports in the multimodal supply chains remain fully independent nodes.

In order to achieve this, a collaborative use of data is crucial. It will lead ports to operational excellence, improve quality of service, and ultimately result in a digitalized port, a Port 4.0.

The digitalization megatrend is transforming industrial processes all over the world, and the shipping industry and the logistics sector are no exception. Digitalization holds valuable benefits in efficiency, security and energy savings, but is also associated with risks. The greatest risk may be disruption by new market entries if ports miss the optimal time to move towards digitalization. That time is now.

2. THE MEGATREND DIGITALIZATION

Seaports must operate in an ever changing environment. The dynamics of the changes and challenges seem to grow, driven by global trade trends, socio-economic developments and industry developments. Seaports must stay innovative and participate in the megatrend of digitalization in order to remain competitive. If the Port Authorities do not keep abreast of industry trends, there will be new, innovative companies disrupting the market, similar to what has occured in other sectors.

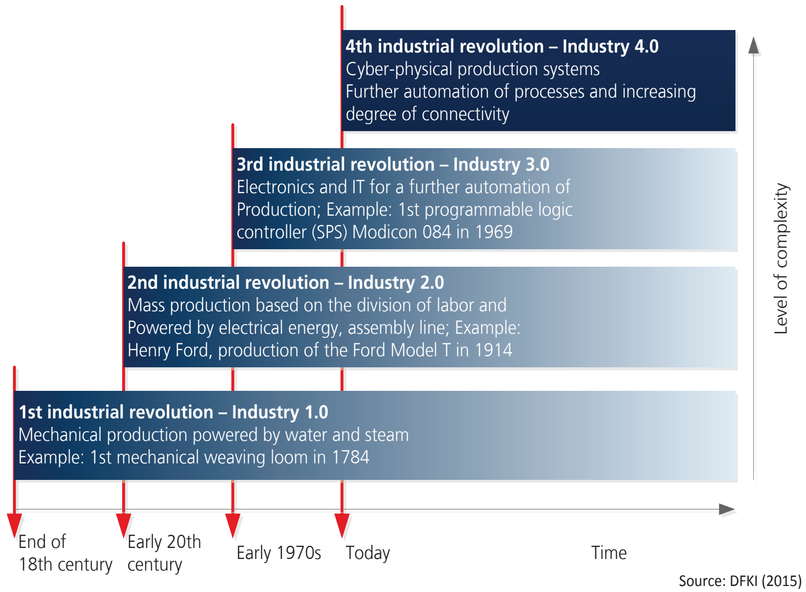
DIGITALIZATION IS THE MAJOR DRIVER FOR INDUSTRY 4.0

The terms digitalization and Industry 4.0 are mentioned frequently today. Digitalization is the technical infiltration of all social and economic sectors. Innovative technologies are not used only to speed up or expand IT and production. Innovations like Internet of Things, cloud computing, cyber-physical systems, robotics, additive production processes, machine learning, augmented reality, blockchain, etc., allow new ways to communicate and new intellectual approaches as well as new business models. In all economic sectors elements of supply chains are scrutinized, improved and interlinked by means of technological innovations. Digitalization is the process of moving to a digital business.

Industry 4.0 refers to the so-called fourth industrial revolution on the basis of cyber-physical systems using the internet. Industry 4.0 combines production activities with state-of-the-art information and communication technologies. Cyber-physical systems monitor physical processes; create a virtual copy of the physical world, the so called virtual twin; and make autonomous decentralized decisions. Through the Internet of Things the workforce, sensors, and applications communicate and cooperate with each other in real-time as future logistics systems.

The two terms Industry 4.0 and digitalization are linked to each other by the fact that digitalization is the major key towards Industry 4.0.

FIGURE 5: EVOLUTION OF INDUSTRY 4.0



Source: DFKI (2015)

INDUSTRY 4.0 BECOMES EVIDENT IN THE LOGISTICS SECTOR, PORTS AND IN THE MARITIME INDUSTRY

The concepts of Logistics 4.0, Maritime 4.0, and Port 4.0 have evolved from Industry 4.0, however, they are not always clearly defined.

Logistics 4.0 (or digital logistics) describes the connection of processes, objects, supply chain partners, and customers using information and communication technologies with decentralized autonomous decision-making.

Maritime 4.0 is more directed towards shipping, and can be explained as the redesign of the maritime industry's supply chains driven by digitalization and interlinking, also making use of autonomous vessels, where appropriate.

Port 4.0 is the overall vision of the digital port using the specific role of ports as the hubs for physical and information flows within the global supply chains, interconnecting all actors involved. Through a value chain network which is neutrally enabled by Port Authorities, digitalization issues like improved connectivity, autonomous systems, Big Data Analytics and automation of knowledge work will lead to greater reliability and efficiency.

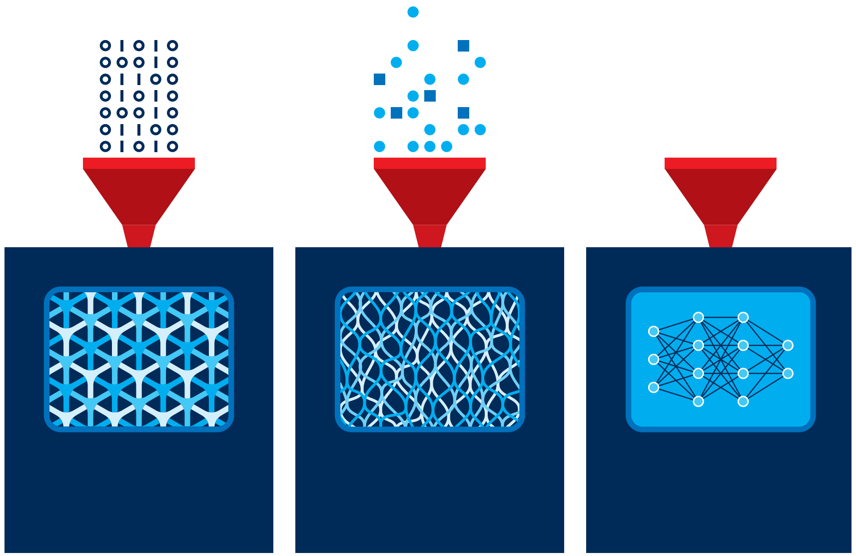
3. THE ECONOMIC RATIONALE

3.1. The economic principles of digitalization

THE IMPLEMENTATION OF DIGITALIZATION RESULTS IN AN ENHANCEMENT OF EFFICIENCY AS WELL AS EFFECTIVENESS

The overall aim of Industry 4.0, Logistics 4.0, Port 4.0, and Maritime 4.0 is to improve efficiency as well as to increase effectiveness. By joining the network, seaports will also benefit from optimized transport flows. Exemplary methods of enhancing efficiency include increasing transparency and process speed, automating processes, as well as reducing errors. An increase in effectiveness can be achieved by improving flexibility, and customizing services, processes, and products. Further, digitalization gives new actors the chance to enter into the market by developing new products and offering innovative digital business models.

FIGURE 6: PROCESS OF BIG DATA ANALYTICS



One term usually used in the context of Industry 4.0, Logistics 4.0, Port 4.0, and Maritime 4.0 is Big Data Analytics. Big Data Analytics is the collection and computation of massive data sets over time, which are usually bigger or more complex than traditional data bases. Industry 4.0, Logistics 4.0, Port 4.0 and Maritime 4.0 may make use of Big Data Analytics.

Using Big Data Analytics, the transport sector creates an opportunity for economically, environmentally and socially efficient, secure and sustainable transport. Big Data Analytics can be used to forecast expected times of arrivals or departures of vessels in seaports, thus enabling a better utilization of suprastructures on port terminals. Data used includes vessel traffic service (VTS) data and tide data.

The value the network of interconnected Smart Ports adds for customers can be described as an overall reduction of costs due to factors such as reduced safety stocks (as a result of increased reliability of supply chains and predictability of delivery dates) and reduced transportation costs (resulting from a decrease in transportation duration). Consequently, connections via ports of the network are more attractive than other connections, giving the connected ports a competitive advantage.

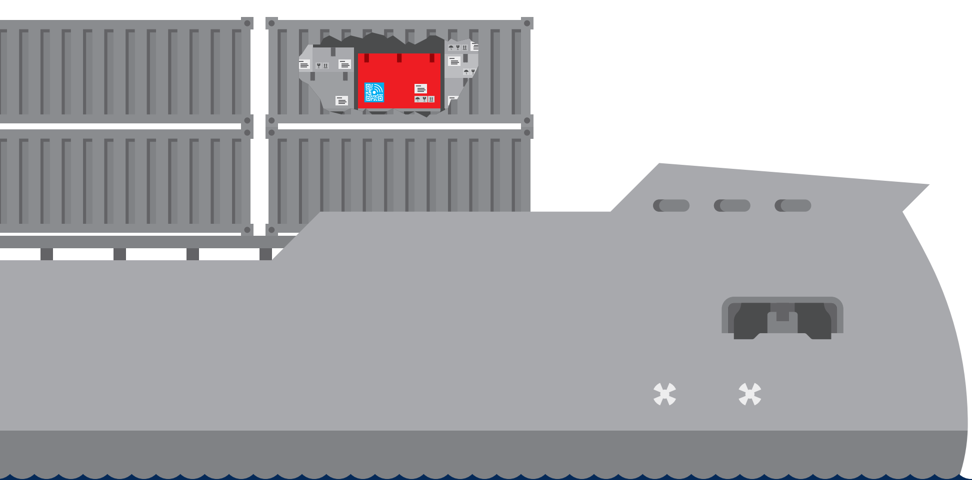
The main prerequisite is the access to complete information regarding transportation through seaports (e.g. times of arrivals and departures of vessels, capacities of individual means of transportation, information on bottlenecks, etc.). The greatest challenge today is to make use of the combined capacity of all transport modes.

However, operators are in competition with each other and system wide optimization often seems unrealistic. Data is collected at individual points of the transport chains, and data can only be exchanged within predefined schemes of actors. Synchromodality, or the simultaneous usage of each transport mode's full capacity can only be achieved if the information exchange barriers are overcome.

A NEW PARADIGM FOR EFFICIENT AND FULL UTILIZATION OF ASSETS AND RESOURCES IS NEEDED IN THE TRANSPORTATION SECTOR

In order to improve the sustainability as well as the economic and environmental efficiency of freight transport and logistics, a new paradigm for the efficient and full utilization of assets and resources is required. This means fully available and transparent intermodal transport services.

A long-term goal is the Physical Internet a truly integrated transport system. E.g., the Alliance for Logistics Innovation through Collaboration in Europe (ALICE) states the following:



> "A truly integrated transport system for sustainable and efficient logistics is based on an open and global system of transport and logistic assets, hubs, resources and services operated in an open environment and framework conditions by individual companies. They are fully visible and accessible to market players hence creating a network of logistics networks. Coordination of logistics, transport, infrastructure and supply networks aim to move, store, supply and use physical objects throughout the world in a manner that is economically, environmentally and socially efficient, secure and sustainable. The system will be based on physical, digital, and operational interconnectivity, enabled through modularization as well as standardization interfaces and protocols." (ALICE 2016)

The Physical Internet is an enabler for a hyperconnected logistics system facilitating seamless asset sharing and flow consolidation. According to recent research results, hyperconnected transportation would lead to overall cost savings of up to 30% on the order, a reduction of greenhouse gas emissions of about 30 to 60% on the order and a modal shift potential of 50% from road to rail or inland waterway. (ALICE 2016)

3.2. Impacts of changes in production onto ports and port areas

During the initial development stages of a hyperconnected global logistics system, there are already noticeable changes in production caused by new production processes. A growing vertical integration of production in the global economy is evident due to increasing digitalization. Individual and custom-made mass production down to lot size one has already become possible. Vertical integration of all production stages allows global, real-time production. Additive production processes (e.g. 3D printing), self-configuring production lines, and

FIGURE 7: INTELLIGENT CONTAINER ON BOARD OF A VESSEL TRANSFERRING DATA VIA A SATELLITE

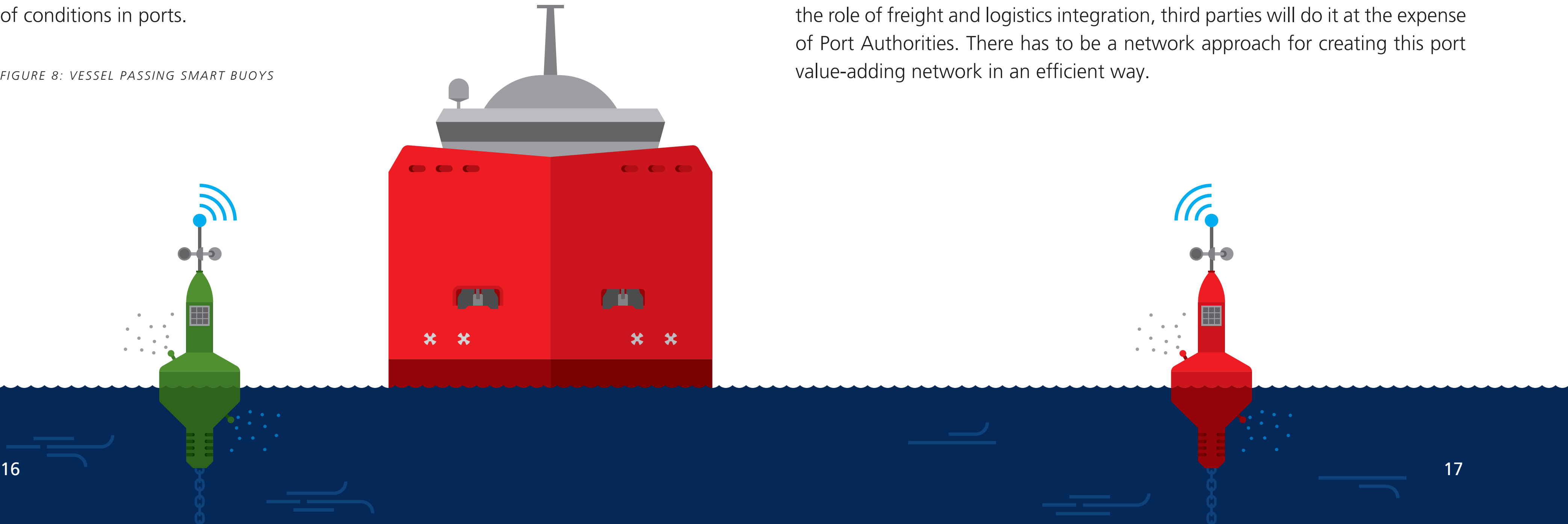
smart parts are all included in the term cyber-physical systems. Exemplary improvements in logistics value chains include smart factories.

Smart factories will possibly be located in close vicinity to the customer or the ports as hubs in the multimodal transport chain. Smart factories are characterized by continuous information exchange between workers, machines, and resources. The production facilities have their own diagnostic and repair capabilities, and the whole factory is largely self-organized. There will be reduced requirements for manual decision-making in smart factories.

The overall aim of smart factories is to increase the flexibility of production. The continuous exchange of data will contribute to the optimal utilization of resources. The production will perform actions such as reorganizing itself via alternative routes if a machine breaks down, meaning that the implementation of cyber-physical systems will also lead to a more mutable flow of goods.

These developments require a redefinition of products and services in maritime logistics. The development of cyber-physical systems will lead to several changes of conditions in ports.

FIGURE 8: VESSEL PASSING SMART BUOYS



The adaptation of Industry 4.0 in port areas and businesses is unstoppable, most likely proceeding at different speeds depending on regions, culture and suitability. Everything that can be digitized will be digitized. The fourth industrial revolution will have an impact on ports comparable to the impact of containers on waterborne transport.

3.3. New products, services and business models

The evolution of Industry 4.0 towards Port 4.0 and the implementation of a hyperconnected global logistics system requires change within the business strategies of the Port Authorities and other maritime actors worldwide. The network of interconnected Smart Ports offers an exchange platform to facilitate this process.

Ports need to consider that they belong to a value-adding network consisting of individual value chains via links and nodes. The described developments require freight and logistics integrators. If the Port Authorities do not take on the role of freight and logistics integration, third parties will do it at the expense of Port Authorities. There has to be a network approach for creating this port value-adding network in an efficient way.

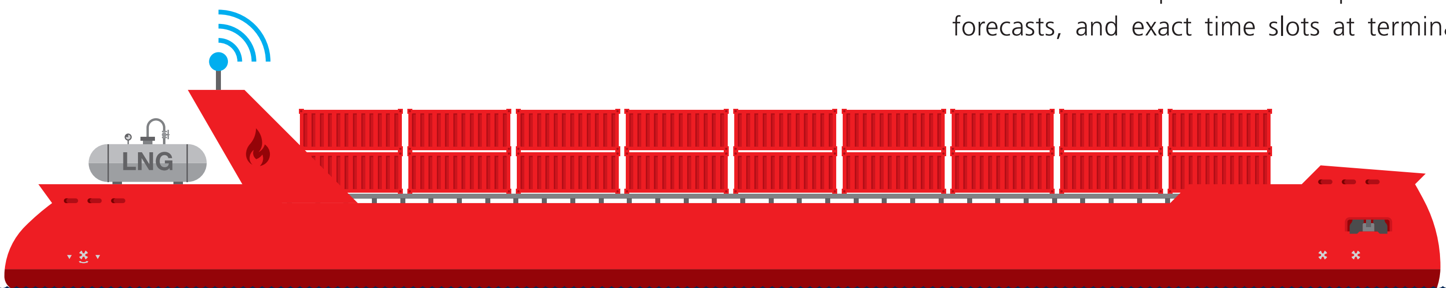
Ports must make use of sometimes already available data and of newly gathered data as well as data sources. This will facilitate the development of the digital business models required by the transport and logistics actors, allowing them to generate value for their customers and themselves and to remain competitive. When implementing digitalization, industries pass through the following four levels of development:

1. Digitize analog data
2. Digitize analog processes
3. Link system with processes
4. Develop digital business model

As of today most ports are in the third level of development, linking systems with processes. However, innovative technologies like the Internet of Things, cloud computing, cyber-physical systems, robotics, additive production processes, machine learning, augmented reality, blockchain, etc., are the enablers for the development of innovative digital business models. These digital business models have the potential to change the value creating process, and the value generated in seaports.

Ports worldwide have a choice, either to proactively make use of these enablers or to leave that to new emerging businesses that will replace them in the fourth industrial revolution. If ports choose the latter option, they may be forced out of the market by disruptive business models. This may also be true for individual value-adding activities.

FIGURE 9: LNG FUELLED AUTOMATED CARGO VESSEL



Disruptive business models are frequently successful because they take advantage of unused capacities, simplify processes, or just use the connectivity opportunities of modern technologies. They optimize industries by implementing scalability. Their global profit is high, while at the same time displaying small margins.

Digital platforms from disruptive business models are often innovative developments that revolutionize entire industries. Uber is an example of a disruptive business model, as they provide a unique service that has proven competitive within a pre-existing market. In contrast to the traditional taxi companies, Uber does not possess a fleet of vehicles, but instead uses private cars for passenger transportation. Another example is Facebook. Facebook is arguably the largest media channel, yet it does not hire journalists. Additional examples include Alibaba and Airbnb, which are companies that respectively facilitate the sale of goods without holding inventory, and facilitate the provision of accommodation without holding property.

The mutual access to massive data between the interconnected Smart Ports allows the development of new products and services (e.g. pricing models, forecasts, and exact time slots at terminals for trucks). This increases the attractiveness and competitiveness of the involved ports, giving them a competitive advantage compared to the ports outside of the network.

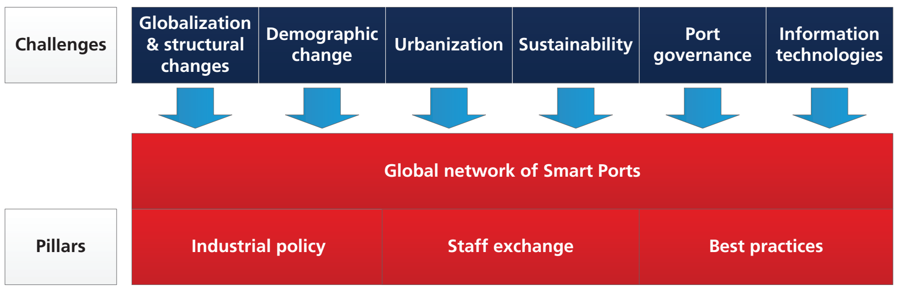
Benefits of the network of Smart Ports include an increasing flexibility or reactiveness. Ports all over the world suffer from bottlenecks at their hinterland connections, as well as from the delayed arrival of vessels. Big Data Analytics can be used to improve reactiveness to congestion or delays, resulting in a more efficient use of assets. Examples include the digital platforms based on shared data which allow the assignment of freight to different transport modes, and facilitate synchromodal transport planning.

All in all, the network provides the connected Smart Ports an environment for the development of a huge variety of digital business models. These digital business models will be established specific to the individual environments of the participating ports.

3.4. Ports in the context of global challenges

Port cities face a number of challenges including increasing urbanization and the need for sustainable port operations. The most striking challenges of seaports are summarized below:

FIGURE 10: CHALLENGES AND PILLARS OF THE GLOBAL NETWORK OF SMART PORTS



CHALLENGE 1: GLOBALIZATION & STRUCTURAL CHANGES

Competitive seaports are a prerequisite for international trade, resulting from the international division of labor. Globalization is a major driver for the increase of international trade and transport volumes. Many production facilities have been moved out of developed economies, however, these economies are still meant to be the major consumers for the goods manufactured abroad.

Recently, growth figures indicate that the degree of globalization shows a declining trend, reasoned by trade barriers and diminishing advantages to produce goods in areas such as Asia. Interestingly enough, Adidas has announced that it will return some of its trainer manufacturing to Europe, within a fully digitized and automated factory.

Worldwide trade and transport volumes have been increasing since the 2008 crisis, and are expected to grow further. Global supply chains and their affiliated freight movements are largely influenced by adjustments in trade and manufacturing specialization, which are a constant source of new challenges for seaports in terms of competition and market share.

Structural changes in production processes take place on a global level. They have an impact on international freight transportation and port throughput. Structural changes include changes in the types of products transported, such as an increased value of goods or the increased exchange of semi-products; changes in trade patterns, such as increasing distances or altered routes; and changes in logistics organization.

The International Transport Forum (ITF) expects the geographical structure of trade to evolve towards increased emphashis on emerging economies. The main developments expected for fast-growing emerging economies include a shift away from low-skilled manufacturing towards services and industry, changes in consumption and domestic demand, and changes in industrial structure. Between 2015 and 2030 freight transport demand is estimated to grow by

4.2% annually, and by 3.3% after that year. The traditional routes between developed economies will grow at a slower pace than corridors between emerging economies. (ITF 2016)

The overall development of emerging and developing economies is related to the shift in the type of commodities being exchanged. This is expressed by an expected increase of the value density of goods being transported to these economies. Furthermore, ITF expects that rising food demand in emerging and developing economies will lead to a substantial increase in food transport volumes.

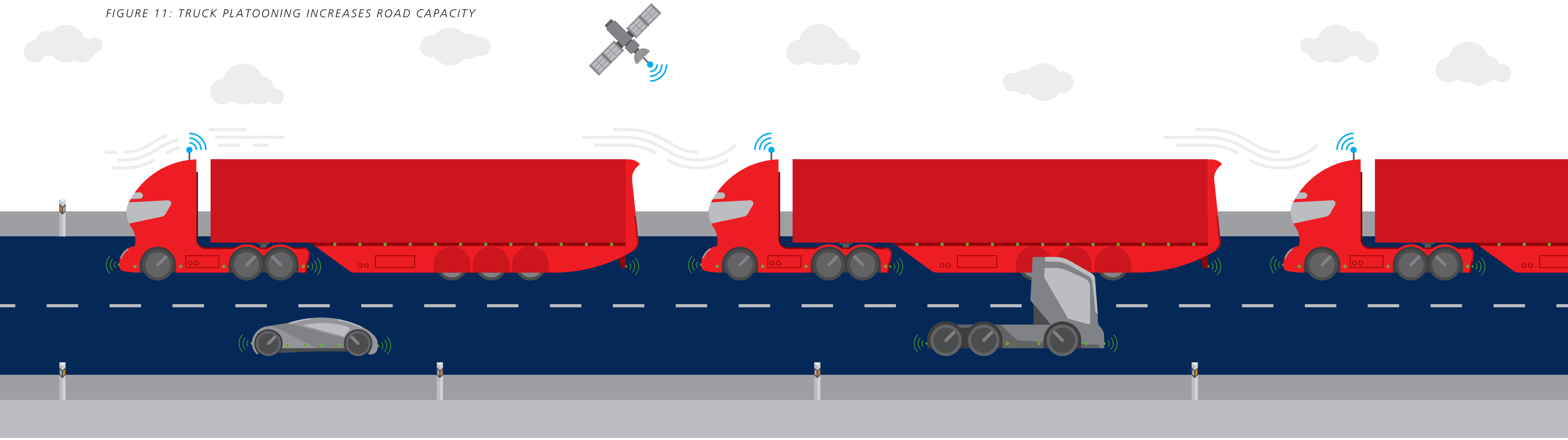
CHALLENGE 2: DEMOGRAPHIC CHANGE

Many industrial countries face the common challenge of an aging population. People get older while at the same time birth rates are not increasing to compensate mortality rates. The overall population is shrinking; less young people have to shoulder the pension costs of a growing number of elderly people. As a result, in almost all European countries, people have to remain in the workforce for longer before reaching retirement age.

For seaports, the experienced workforce is a gift. However, some employees require suitable working conditions that account for physical limitations, as well as having a need for digital equipment that is accessible and intuitive to use. Furthermore, employees must receive sufficient training to use the emerging new technologies.

Seaports, like all other employers, must remain attractive to the future work force. Although the term 'war for talents' may sound rather martial, it describes the competition in the labor markets today and in the future, where the power structures have changed completely for the young, well-educated professional. Today and in the future, the companies search for employees. The situation was different in periods with high unemployment rates like in the 1980s.

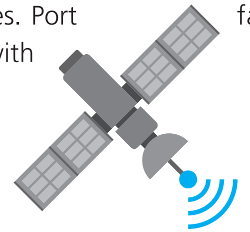
FIGURE 11: TRUCK PLATOONING INCREASES ROAD CAPACITY



CHALLENGE 3: URBANIZATION

Ever since the industrial revolution there has been a trend towards urbanization – leaving rural areas to live in cities. This trend continues, as the growing populations in Africa and Asia look for better lives in the cities. Considering that the rural population of India and China is 857 million people and 635 million people respectively, the global share of people living in urban areas is expected to rise from 54% in 2014 to 66% in 2050 (United Nations 2014). However, in the so-called developed countries the urbanization rate is already high with, the percentage of people living in urban centres being 82% in North America and 73% in Europe (United Nations 2014).

The growing cities require sustainable development, especially in lower- to middle-income countries. Port facilities play a major role for supplying these cities with goods, raw materials, and passenger transportation services. At the same time ports are often situated in the heart of cities, leading to land use conflicts between ports and housing areas.



New technologies in cities such as Smart Cities and Smart Ports can contribute to the solution of these challenges by making the transport flows and port operations safer, more efficient, and more seamless. Increasingly improved accessibility through better working port facilities provides cities a more affordable supply of goods and services.

CHALLENGE 4: SUSTAINABILITY

Sustainability has developed itself into a major and undisputed goal for the development of societies. Ecology, economy, and society are the three pillars of sustainability. The general definition of sustainability can also be transferred to seaports. Port Authorities need to become pro-active partners in the development of the region and of logistics chains via sustainable ports.

Sustainability and scarcity of resources are drivers towards technological innovations and new strategies for seaports. The implementation of innovations may increase the sustainability of seaports. Ways to reduce local emissions in seaports from fossil fuels include the use of alternative fuels such as LNG, electrified vehicles and the optimization and automation of processes.

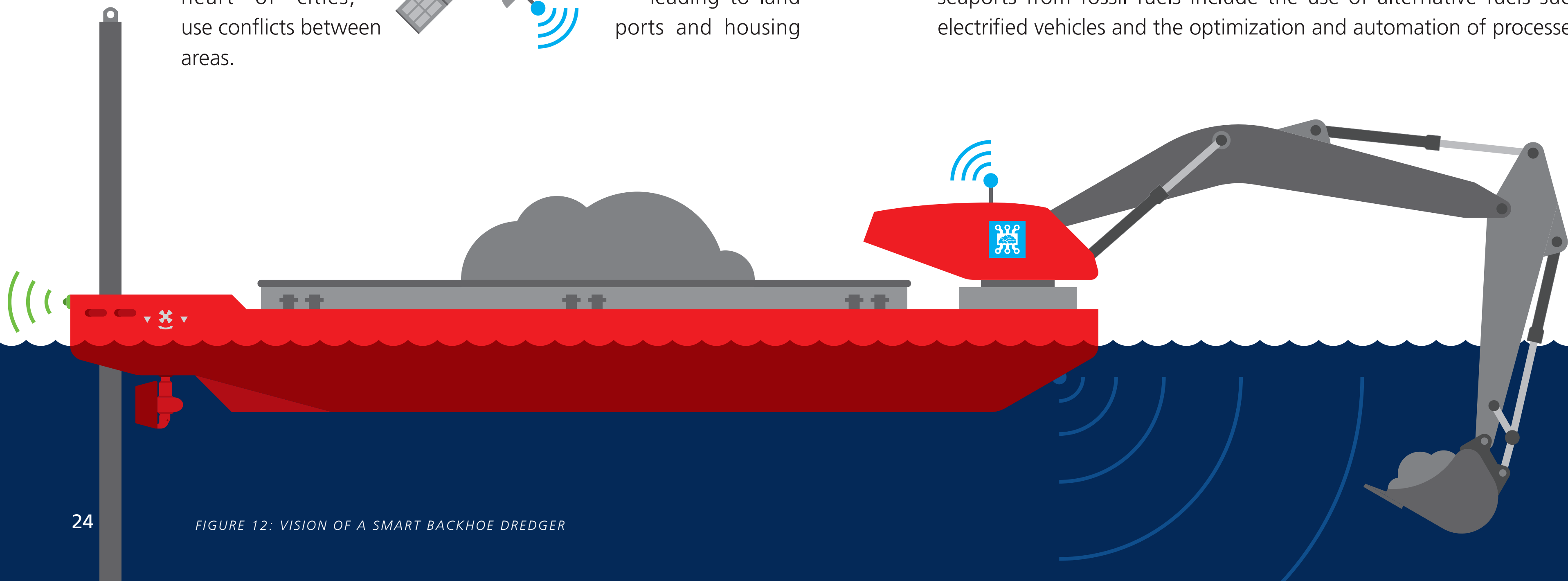


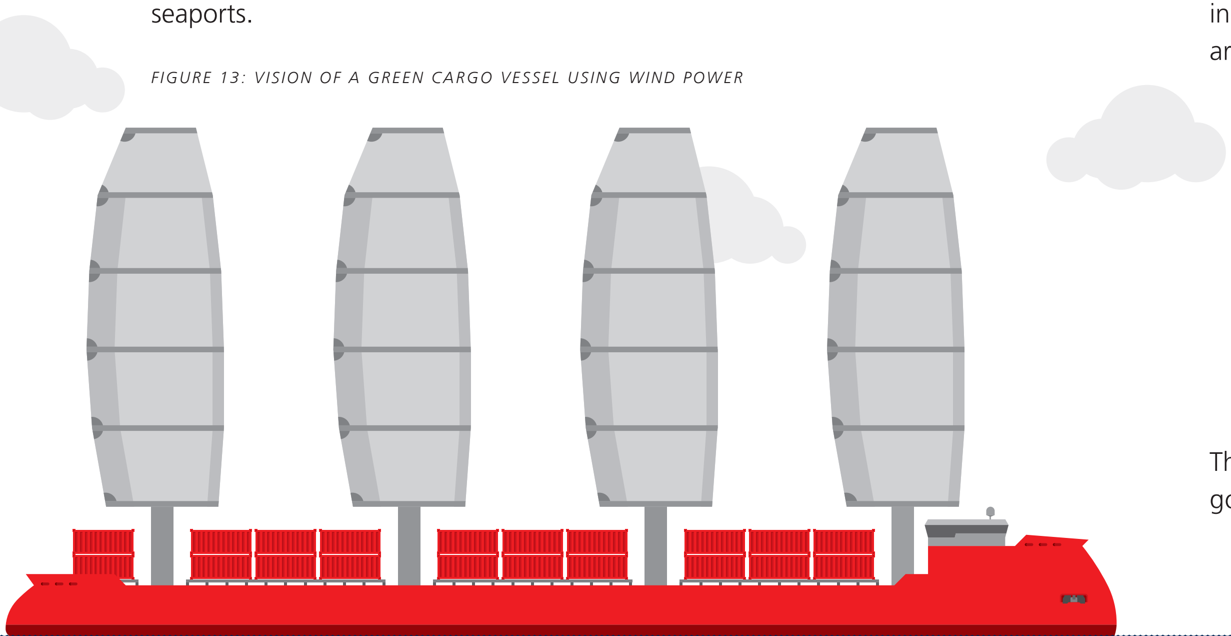
FIGURE 12: VISION OF A SMART BACKHOE DREDGER

Economic sustainability means that current economic activities shall not compromise future performance. This requires seaports and Port Authorities to prepare for the future to remain competitive and operational. Social sustainability describes the requirement that ports take care of their employees regarding their education, health, and working environment.

The consumption of resources is relevant in the context of increasing scarcity of resources, especially fossil fuels. In connection with an increasing scarcity of raw materials, new strategies are required to enable resource-efficient and sustainable port operations. Firstly, a circular economy reduces the environmental impact of economic activities, and also creates new transport demand connected to reverse logistics. Secondly, it generates a decisive competitive advantage for ports supporting circular economy.

The following chapters provide insight into the opportunities arising from the realization of Port 4.0 and the implementation of cyber-physical systems in seaports.

FIGURE 13: VISION OF A GREEN CARGO VESSEL USING WIND POWER



4. THE VISION OF THE DIGITAL PORT

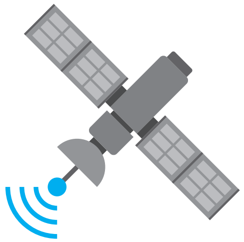
4.1. The concept of interconnected Smart Ports

The network of interconnected ports consists of individual Smart Ports on the one hand and Smart Ports interlinked to a network of Smart Ports on the other hand. Smart Ports make use of technological enablers to make their processes more flexible, robust and efficient. The network of Smart Ports is characterized by the three main pillars: coordinated industrial policy; staff exchange; and sharing best practices among the participating Smart Ports. The idea is to tranfer the idea of the Physical Internet to the maritime sector.

The global network of Smart Ports is an informal network of ports willing to collaborate, fully taking into account the ports' independence. Through digitalization, the network is realized as an IT-framework without a central platform or authority. The ports in the multimodal supply chains remain fully independent nodes. The key components of the global network of Smart Ports' architecture are:

- Port Authorities as neutral brokers for services for actors from the maritime sector
- Smart containers as smart logistical units organizing their own transport through the transport network
- Service level agreements for each section of the transport chain, e.g. a guaranteed quality of service for each transport
- Physical and digital connections between Smart Ports and other logistical nodes

The global network of Smart Ports aims to optimize maritime logistics by sharing good practices, concerning innovative solutions within the network. It is supposed to interlink information and data between participating ports, creating a breeding ground to jointly develop new, future-oriented and innovative solutions, products and digital business models within a value creating network. Examples include pricing models, forecasts, and exact time slots at terminals for trucks. This increases the attractiveness and competitiveness of the involved ports, giving them a competitive advantage.

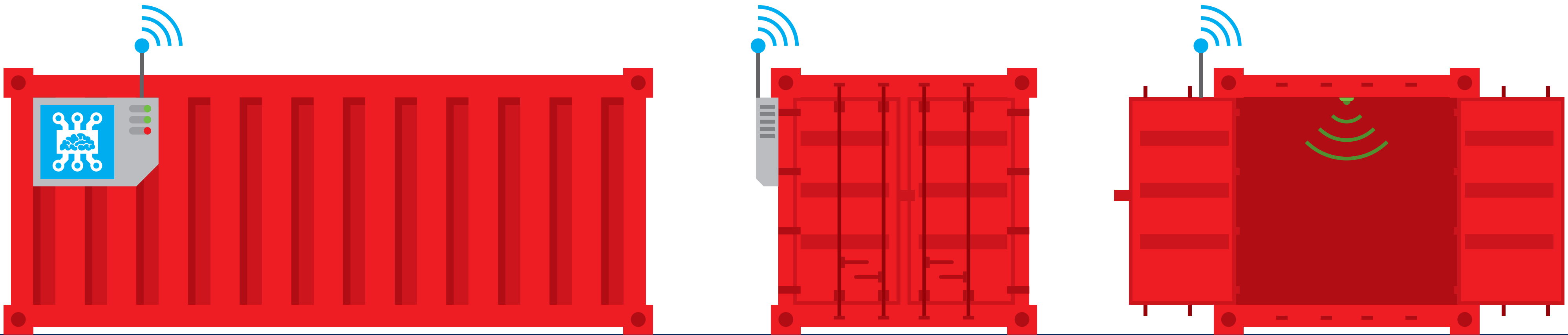


Via the network a digital supply chain, encompassing important ports on all continents, will be established. Product and traffic data will be exchanged in globally acceptable standards within an international network of ports: in Asia and Oceania, the Americas, Africa and Europe, including the north-German ports, making a frictionless logistics network. This means that when a smart container is shipped from one port, subsequent ports in the maritime supply chain via the network of Smart Ports have access to detailed information about the current state of the maritime supply chain and possible challenges that the work load terminals and carriers will be facing. Examples include information on which kind of unloading and transport capacities are required and when they are needed, or whether dangerous or perishable goods are to be prioritized. The network provides all relevant information. Information about trends and issues like breakdowns are transmitted mutually. This is especially relevant and interesting for the logistics and production industry.

From the customer's perspective, interconnected Smart Ports are able to warrant a guaranteed throughput time from entry of the smart container at the port of origin to the destination port. A decentralized IT-network for smart container transport within the network of Smart Ports will probably be established. Within this network, the transport of smart containers is conducted as a time-limited service between the parties in the supply chain.

The value the global network of Smart Ports adds for customers is an overall reduction of costs due to reduced safety stocks (as a result of increased reliability of supply chains and predictability of delivery dates) and reduced transportation costs (resulting from a decrease in transportation duration). Consequently, connections via ports of the network are more attractive than other connections, giving ports in the network a competitive advantage.

FIGURE 14: SMART CONTAINER



Benefits of the global network of Smart Ports further include an increasing flexibility or reactiveness. Ports all over the world suffer from bottlenecks at their hinterland connections, as well as from the delayed arrival of vessels. Here, Big Data Analytics can be used to improve reactiveness to congestion or delays, resulting in a more efficient use of assets. Examples include digital platforms based on data from the network which allow the assignment of freight to different transport modes, and facilitate synchromodal transport planning.

The network can be understood as a hyperconnected maritime logistics system interlinking the actors of maritime supply chains on different levels. It aims at meeting the grand challenge in global logistics sustainability to be economically, environmentally and socially efficient and sustainable. Thus, the network of digitally and physically connected Smart Ports is the transfer of the Physical Internet to the maritime sector. The network provides the connected ports an environment for the development of a huge variety of digital business models. These digital business models will be established specific to the individual environments of the participating Smart Ports.

4.2. Future scenario “Maritime Transport“

New technologies have a high impact on many industries, including the maritime transport sector. Shipping, navigation, nautical solutions, maritime transport, and transshipment will benefit from the digitalization age.

In the near future, autonomous vessels will sail unmanned, reducing the operating costs and increasing safety of maritime transport. One side effect of this automation is improved working conditions for seafarers, since they can now stay at home and do not have to be at sea for months. The crew works

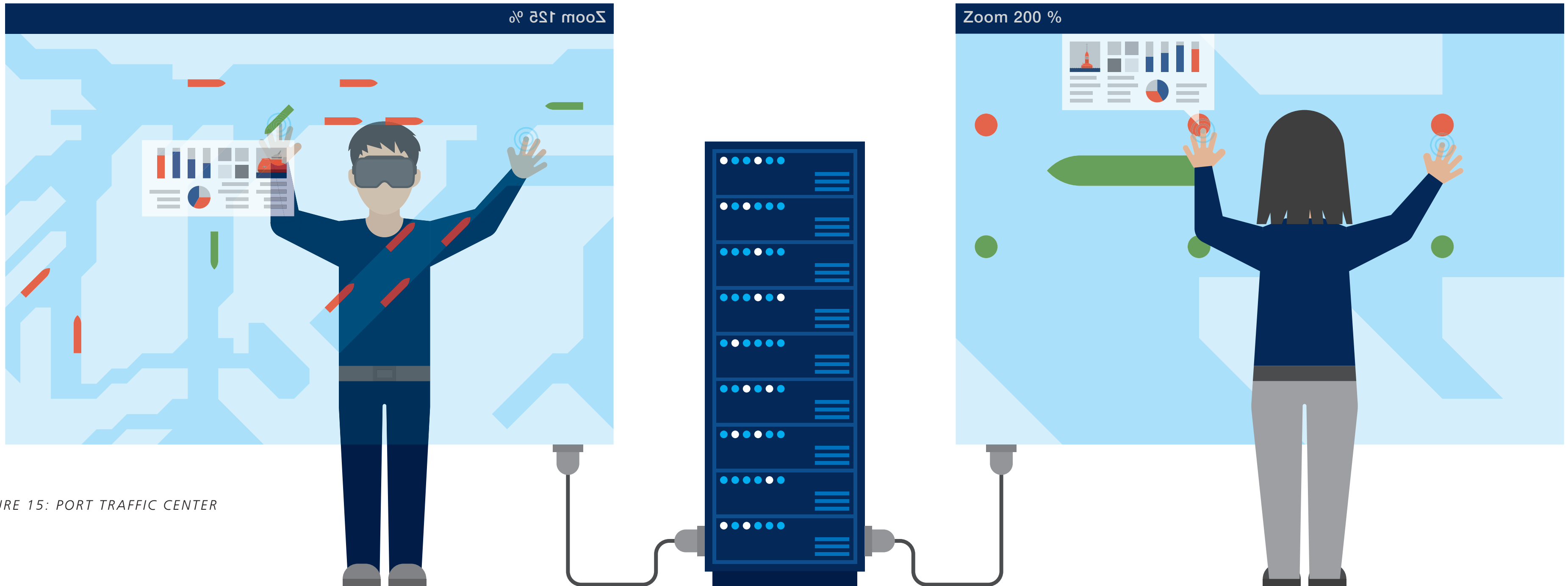
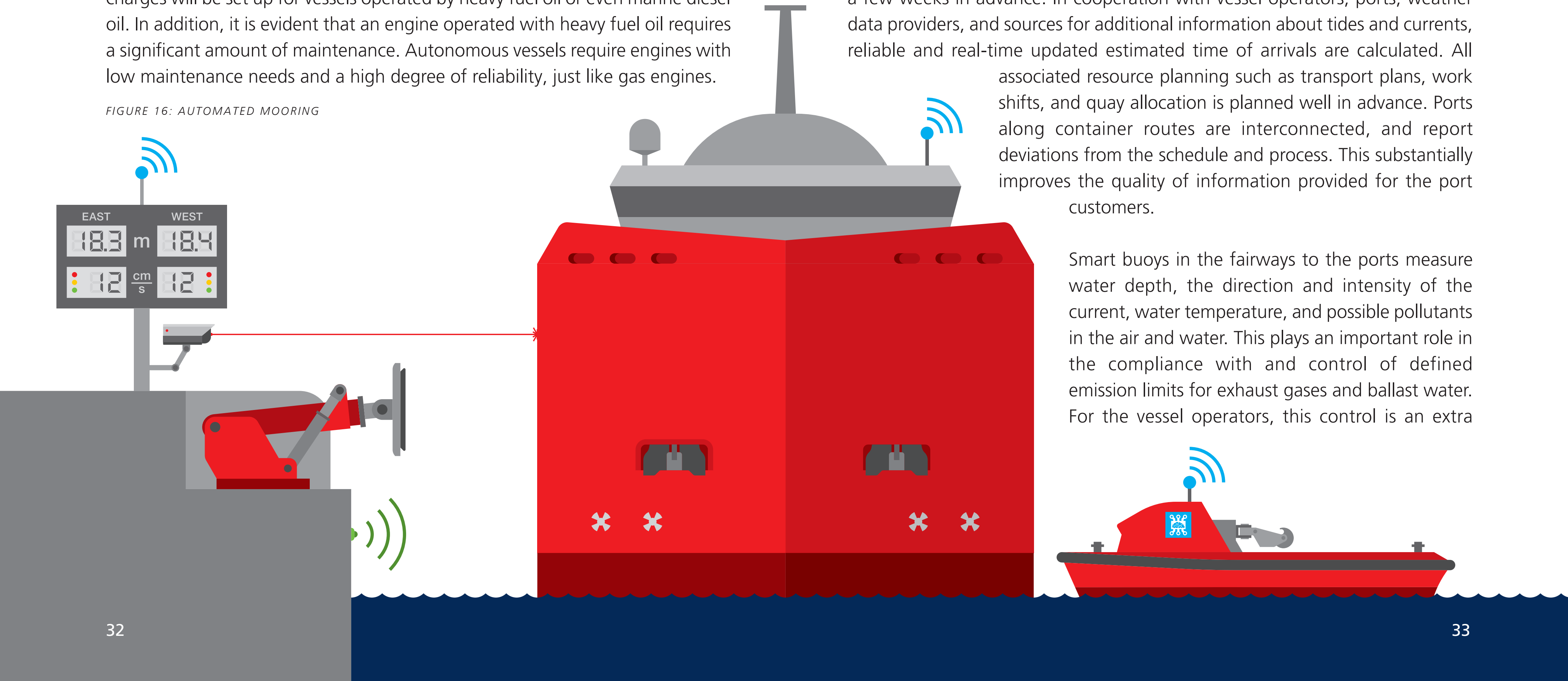


FIGURE 15: PORT TRAFFIC CENTER

onshore and boards the vessel once it reaches coastal waters. Local expertise of the pilots and sea officers is still required. The deployment of autonomous vessels will not immediately replace all manned vessels, there will be decades in which both systems exist. First, we will see autonomous vessels in long distance bulk and container liner services, as well as in ferry operations.

Despite today's reluctance to deploy LNG more in shipping, in the future autonomous vessels as well as manned vessels will largely be operated by LNG for various reasons. Firstly, environmental regulations do not end with the reduction of sulphur content in the exhaust gases (SECA). Secondly, high port charges will be set up for vessels operated by heavy fuel oil or even marine diesel oil. In addition, it is evident that an engine operated with heavy fuel oil requires a significant amount of maintenance. Autonomous vessels require engines with low maintenance needs and a high degree of reliability, just like gas engines.

FIGURE 16: AUTOMATED MOORING



A comprehensive LNG bunkering network is established in the North and the Baltic Sea. Barges shuttle LNG between the LNG import terminals and the berths within the port where the vessels are bunkered. There will also be installations in ports, supplying the vessels with electric energy. Depending on the specifics in the country and the costs for electric energy, this may also involve LNG PowerPacs and barges as electric energy suppliers. Feeder ships as well as some tugboats will use batteries or a diesel-electric engine. There will also be a few instances of wind-powered or wind-supported vessels in the port.

The Nautical Central Office of the port knows the exact arrival time of the vessel a few weeks in advance. In cooperation with vessel operators, ports, weather data providers, and sources for additional information about tides and currents, reliable and real-time updated estimated time of arrivals are calculated. All associated resource planning such as transport plans, work shifts, and quay allocation is planned well in advance. Ports along container routes are interconnected, and report deviations from the schedule and process. This substantially improves the quality of information provided for the port customers.

Smart buoys in the fairways to the ports measure water depth, the direction and intensity of the current, water temperature, and possible pollutants in the air and water. This plays an important role in the compliance with and control of defined emission limits for exhaust gases and ballast water. For the vessel operators, this control is an extra service since many shippers require a sound documentation of the environmental balance. Smart buoys add extra data for real-time depth profiles, thus making it easier to navigate within certain segments with Ultra Large Container Vessels or large bulkers. Smart buoys communicate with vessels passing by and ease the navigation, thereby increasing safety and accessibility of the ports.

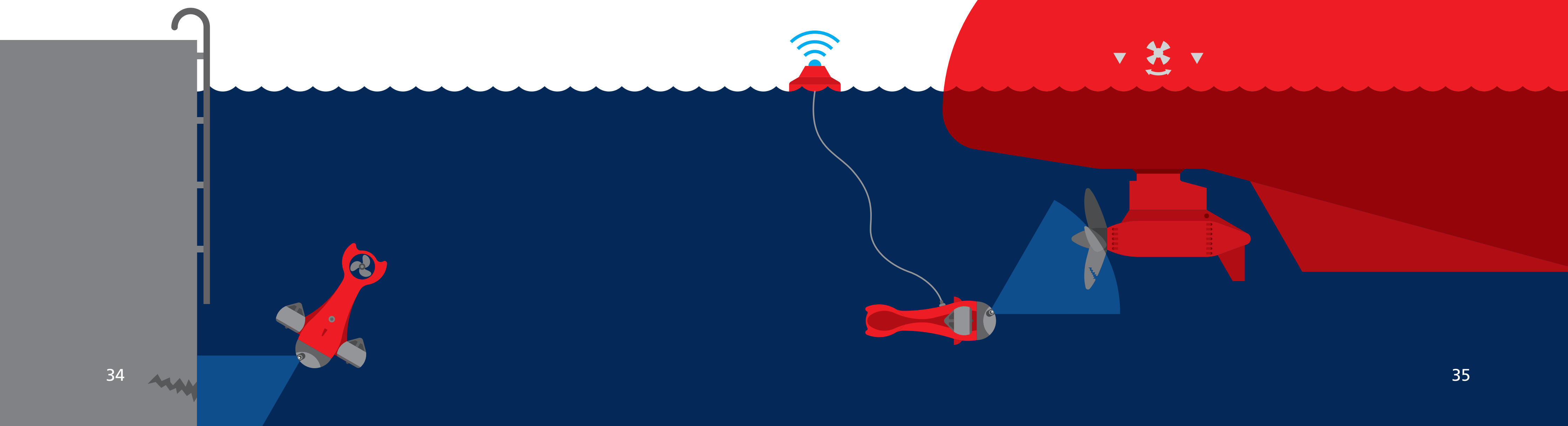
Tugboats are still necessary to maneuver vessels to the terminals. The future tugboats are semi-autonomous and fitted with sensors. As part of the overall port data system, they use real-time data of current and depth profiles and measure the vessel's movements through onboard sensors. Thus, semi-autonomous maneuvering is carried out with greater efficiency, precision, and safety. Pilots or captains are able to steer the tugboats directly from the bridge of their vessel.

To moor the vessel automatically to the berth, sensors and cameras support the maneuvering. The captain receives exact information about the distance between vessel and quay, and visual assistance is supplied if necessary. In order to avoid damages and to shorten the mooring time, these new innovative technologies are used in the port area.

Autonomous underwater drones are deployed for a number of tasks, maintenance being a key application. The drones monitor the port's underwater infrastructure regularly to ensure integrity, especially after events like storm tides. The data they supply adds to the predictive maintenance database of the port. Underwater drones also check the need for dredging, and provide service inspections to the vessel owners by checking hull and propellers through high-definition cameras. Drones are also used to clean the hull.

In addition to standard containers, there are already many containers on board fitted with technologies to monitor and control the status of the load unit, the cargo, and the position. Containers that are even more technologically equipped will be able to communicate with the port's synchromodal traffic management

FIGURE 17: AUTONOMOUS UNDERWATER DRONES



system, the Port Traffic Center. They will book themselves into hinterland transport offers, based on their settings regarding transport time and costs.

5. OUTLOOK

This booklet marks the first publication within the context of interconnected Smart Ports. In April 2017, a comprehensive scientific publication will be issued including additional future scenarios for ports, and a more detailed analysis of the challenges to come. It will be available at the Fraunhofer-Bookshop:

Internet Address:
https://www.verlag.fraunhofer.de/bookshop/buch/Digitalization-of-Seaports-Visions-of-the-Future/247608

A network is only as strong as the activities of its members. The network of interconnected Smart Ports offers ports around the globe the opportunity to become a part of the network that actively shapes the future, and reaps the benefits together.

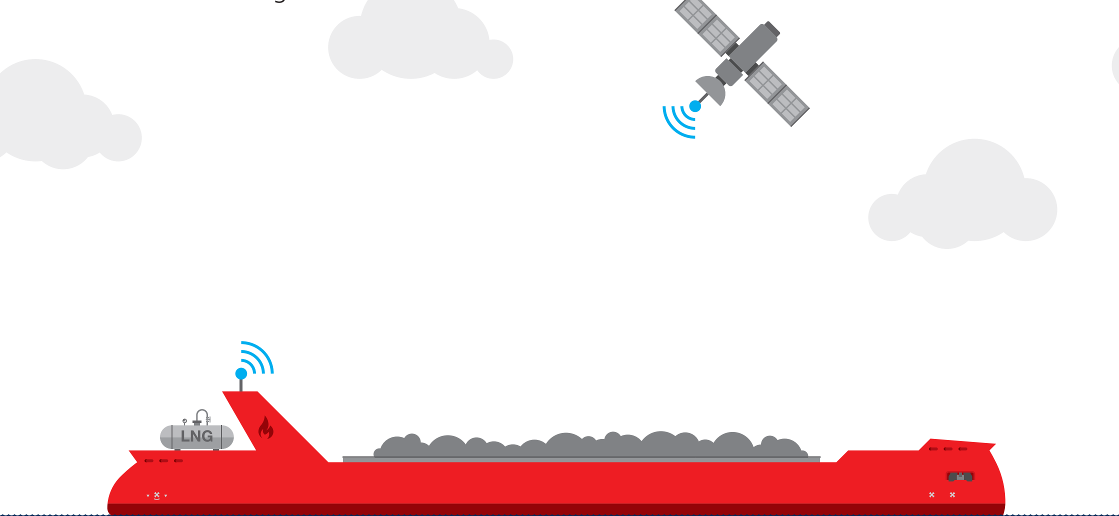


FIGURE 18: AUTONOMOUS BULK CARRIER FUELLED WITH LNG

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