SMART PORT SOLUTIONS FOR REMOTER AREAS

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Abbildung 1: Port of Hamburg

Port of Hamburg Marketing

Content

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LIST OF ABBREVIATIONS

AnIBV	Anlaufbedingungsverordnung
ANSW	Advantage National Single Window
API	Application Programming Interface
BSH	Federal Maritime and Hydrographic Agency
CTA	HHLA Container Terminal Altenwerder
ECDIS	Electronic Chart Display and Information System
EDI	Electronic Data Exchange
EMSW	European Maritime Single Window
ESCAP	Economic and Social Commission for Asia and the Pacific
GAS	Gate Appointment Systems
HHLA	Hamburger Hafen und Logistik AG
HIS	Commissioned port information system
HPA	Hamburg Port Authority
HPC	Hamburg Port Consulting
HVCC	Hamburg Vessel Coordination Center
IAPH	International Association of Ports and Harbors
IoT	Internet of Things
IMO	International Maritime Organization
ITS	Intelligent Transport Systems
NSR	North Sea Region
PCS	Port Community System
RFID	Radio frequency ID
RTA	Requested Time of Arrival
SDGs	Sustainable Development Goals
SETA	Single European Transport Area
TEN-T	Trans-European Network-Transport
TFEU	Treaty on the Functioning of the European Union
VTC	Vessel Traffic Service Centre
WP	Work Package
WPSP	World Ports Sustainability Programme

1 BACKGROUND AND INTRODUCTION

The North Sea Region (NSR) is one of the logistics zones in Europe: The largest seaports, but also many intermodal transportation nodes are in the North Sea Region. Those intermodal nodes are outstanding for the transportation of goods to and from the supply and demand markets. To increase attractiveness of a location along with its market potential i.e., the achievable market, efficient, smart, and ecological transportation networks are needed. The intermodality should enable a concentration of transnational traffic and long-distance flows, and because of their integration, provide for a highly resource efficient infrastructure use.

Currently, the Trans-European Network-Transport (TEN-T) policy is putting a strong focus on the development of the Core Network, the major transport axes across Europe. The whole trade and business network is not only depending on its major nodes but also on its hinterland.

The Interreg VB North Sea region project CONNECTing North Sea Region's TEN-T nodes - Support intermodality growth in the North Sea Region through smart efficiency enhancements (NSR CONNECT) aims at raising the efficiency of transport flows in a holistic approach. The project will thus include both major and remoter transportation nodes to establish learning opportunities.

The overall project objective is to support smart intermodality growth in the NSR through efficiency enhancements. The detailed project objectives are:

- Implementation of new smart processes and tools (smart intermodality),
- Developing of strategies for smart efficiency enhancements (smart involvement)

The perspective of transportation is transnational. New are the instruments for implementation and involvement.

The NSR CONNECT's third work package (WP) fosters the identification of remoter areas' bottlenecks in the intermodal network. The main objective is to identify transnational barriers and bottlenecks in terms of connectivity, smart technologies, and logistics processes, which impede the implementation of the TEN-T core and comprehensive network, more precisely the interface of the core and remoter nodes. The results of studies (e.g., TEN-T corridor studies) and projects (e.g., INTERREG) are considered with a focus on regional/remoter intermodal nodes, which are threatened of being detached from major hubs due to a loss of competitiveness i.e. due to lack of capacity. The paper on hand is one of three reports in the framework of this activity. It focusses on smart port solutions for remoter areas and/or small ports. This paper as well as all project results will be published on the project's website.

NSR CONNECT Show Case

https://northsearegion.eu/north-sea-connect

#NorthSeaConnect

2 DEFINITIONS

2.1 Smart Port

The seaport is an infrastructure hub, where different transportation companies are connected and complement each other to achieve the goal of transporting people and goods in the most proficient, effective, and fastest way. In order to achieve all this in a targeted manner, ports are managing huge amounts of various types of traffic and related to this even larger operational data. In addition, ports with more operating data are directly connected to the surrounding environment. This implies that a city and a region are connected to the port by their infrastructure, but their interdependence is also reflected in various links such as ecology, social quality, and economy etc.

For the growth of port services, sometimes even exceeding its capacity, cities and port areas have also felt the effects of overcrowding. In addition, the services provided by ports are changing to improve quality at affordable prices in a shorter period of time.

For the above reasons, the port system needs to rethink to meet these challenges, and the simplest and inexpensive or rather competitive way is to integrate newly developed technologies into daily operations such as the Internet of Things (IoT), Big Data, and radio frequency ID (RFID) etc.

Port requirements have changed, but their surroundings have also changed on the sea and coast side. The more environmentally friendly, automated, fast response system, or, in short, the smarter system, the technology-modified vessels and the continual development of cities. Smart homes, smart parking and public transport, real-time measurement of air, water and soil pollution in cities, automation, energy efficiency, waste and ballast management, and ship navigation help require the same standards for ports. Operational solutions must be provided for new demands and a platform must be built to integrate all stakeholders inside and outside the border. Future ports must embrace and overcome specific problems without negatively impacting their environmental and social impacts on the wider community, and technologies like IoT offer them the opportunity. [1]

Due to all these different aspects, it is not easy to name a universal definition of a smart port but the project SPEED in the ‘Interreg 2 Seas’ program has set up a very clear and content-structured definition of the term smart port which is presented below.

„By a smart port we mean a port that develops resilience and autonomy in its operations and infrastructure. A smart port is a port that optimizes in-, port- and out-bound flows of goods and information, leads a sustainable development, guarantees safe, resilient, and secure activities through the capabilities of its (extended) port community and enabling technologies.

To become a smart port, we need to develop and show increased maturity in:

- Integration and efficiency of port operations
- Adaptive, balanced, effective, and synchronized modality shifts
- Robust end-to-end cybersecurity
- Energy and environmental performance
- Digital capabilities: a digital talent pool and growth-supporting factor markets”[2]

[1] Bojić, Filip/Bošnjak, Rino/Gudelj, Anita: Review of Smart Ports in the European Union, p. 5.
[2] SPEED project: The Smarter Ports Manifesto. URL: https://www.smartportsecosystem.com/.

2.2 Remote Area

The terms Remote Area and Rural Area are often used synonymously. At the beginning, the two terms are delineated separately. In the further course of this report, however, the terms will be used synonymously and only the term remote area will be used.

The EU defines the term Remote Area as follows: “Local and regional administrative communities, most of them outside urban clusters characterized by difficult physical access, mostly due to geographical/natural divide (islands and/or mountains included, among others) accompanied by limited or less frequent public transport and/or difficult digital connectivity. These areas can share the same aforementioned features of ‘rural areas’. The EU outermost regions as set out in Article 349 TFEU are also considered as remote ones.”[3]

This is contrasted with the term Rural Areas: “Local administrative communities outside urban clusters, mostly characterized by lower population density, specific sociogeographical and cultural image, vicinity to natural resources and therefore different economic prospects, while at the same time with identified needs for further improvement of specific services aiming at youth as well as general population.”[4]

2.3 Comprehensive network

The TEN-T Guidelines define the network's objectives as well as the specifics of the infrastructure that comprises its core and comprehensive networks. The core network is the network's backbone, with a completion date of 2030 set, whereas the comprehensive network is larger.

The TEN-T also includes measures to encourage the development of refueling and charging technologies of alternative fuels, as well as the deployment of Intelligent Transport Systems (ITS) for various modes. The Connecting Europe Facility II (CEF II) contributes to the development of the TEN-T by co-funding projects, with a focus on modes that have the greatest potential to support a sustainable transport system, such as railways and inland waterways, though traffic management, including ITS, is supported for all modes.

Article 37 of the TEN-T Guidelines emphasizes that transportation infrastructure must provide for seamless mobility and accessibility for all potential customers, however the examples offered are for individuals with limited mobility rather than those from a specific location. Considering that one of the aims of the TEN-T was to promote cohesion by improving accessibility and connectivity across various regions, it is undoubtedly a lost opportunity that Article 37 does not include a reference regarding helping to improve accessibility for people living in particular regions, such as low-density and depopulating areas.[5]

Low density and depopulating areas have distinct demographic and geographical characteristics, which collide with the requirement to offer trustworthy and comprehensive classifications. EU regulations and guidelines have assisted in the definition of specific regions influenced by demographic or geographical factors. The notion of low-density and lightly populated regions is defined in the Treaty of the European Union (Art.174).[6]

[3] European Union: Conclusions of the Council and of the Representatives of the Governments of the Member States meeting within the Council on raising opportunities for young people in rural and remote areas, p. 193/10.
[4] Ibid.
[5] European Parliament: Transport infrastructure in low-density and depopulating areas, p. 54.
[6] Ibid. p. 7

Unfortunately, economic growth, trade, or commerce, or even commuting, does not follow national or EU boundaries. The same is valid for the solution, which is something that must be recognized. It would be foolish to leave out remote areas when allocating funding for innovation. The potential for new solutions is at least as big as in urban areas.[7]

With reference to the North Sea Region, it should be mentioned that the North Sea Region's rural areas are becoming less appealing to families and companies due to a digital gap. There is no appropriate digital infrastructure. Digital skills are not being trained sufficiently. Local governments are frequently unaware of their upcoming digital demands, and end users have inadequate abilities to generate an appropriate level of demand.[8]

[7] Kyllönen, Merja: Remote areas ideal for testing transport solutions, in: The Parliament Magazine. URL: https://www.theparliamentmagazine.eu/news/article/remote-areas-ideal-for-testing-transport-solutions.
[8] CORA project. URL: https://northsearegion.eu/cora/.

3 PRINCIPLES TOWARDS A SMART INNOVATION ECOSYSTEM LOGIC

Overall, there are currently three big different aspects that suggest ports need to become smarter. The port business as we currently know it is under enormous pressure, so smart changes can ensure purposeful, economic, and environmental success.

The first reason why ports need to become smarter is because conservative management recipes destroy economic value. This is because old business models have their focus on physical trade volumes, cut-throat competition, commoditized service offerings, externalized environmental costs, protectionist- and fragmented value chains, have outlasted their business- and societal usefulness. A lot of the different logistics competitors across the chain operate at near-zero, or sometimes even negative margins.

Secondly, the logistics player shouldn't get a license to operate without sustainability. Shipping is also responsible for parts of global emissions and is lagging enormously behind in the adoption of Industry 4.0, while the industry is currently experiencing an upswing in terms of sustainability and digitalization. One good example is the E-way bill. E-way bill or electronic-way bill is a document introduced under the Goods and Services Tax (India) regime that needs to be generated before transporting or shipping goods worth more than 50,000 Indian rupee (approximately 590 Euro) Euro within state or inter-state. It is usually a unique bill number generated for the specific consignment involving the movement of goods.[9] Another very illustrative example is the Just-in-time – concept. Just-in-time refers to a delivery method in which the required goods are delivered at the exact time and in the exact quantity needed to keep storage at the processing site as low as possible. As a basis for better data exchange, the International Maritime Organization (IMO) has now presented a guide. The "Just in Time Arrival Guide" offers a holistic approach that takes both contractual and operational aspects into account. It is not only intended for shipping companies, but equally for charterers, port authorities, terminal operators, ship agents, shipbrokers, and other service providers. All these players ultimately play an important role in implementing the necessary adjustments.[10]

One last common aspect for changing towards a smart innovation ecosystem logic are locked-in silos that are unable to innovate. Today, ports are capacity niches that have been optimized into silos instead of being fully integrated into global supply chains. A major problem here is the market's free delivery and return offers, which leads to the supply chain being driven into a price competition trap and into the optimization of old and siloed business models. For this reason, connectedness, end-to-end efficiency, reliability, and sustainability in port operations is required that drive disruptive growth in digital industries.[11]

Generally, four megatrends can currently be observed that are necessary for ports to become smarter. The first trend refers to conservative management recipes that destroy economic value. Another megatrend is the required need for a sustainability license to operate. The third megatrend that is currently predominant is the elimination of locked-in silos that are unable to innovate. Furthermore, the fourth and last megatrend are smart port platform dynamics that will drive economic growth and integration. These are made up of vertically integrated global chain platforms, locally clustered smart port and inland corridor platforms, backwards-integrating e-commerce giants and industry newcomers

[9] Business Standard. URL: https://www.business-standard.com/about/what-is-e-way-bill.
[10] Green Shipping News: IMO legt Leitfaden für Just-in-time-Anläufe vor. URL: https://www.green-shipping-news.de/imo-just-in-time/.
[11] SPEED project. URL: https://www.smartportsecosystem.com/test-pagina.

from new technology fields. In the further course of this report, the various smart port platform dynamics will be discussed in more detail.

3.1 From price competition to co-opetition in a smart port ecosystem

The competitive game in the smart ports industry has been performed between several digitally focused ecosystems, which will be fueled by the four digital platform innovations mentioned above. The ability of enterprises to envisage ecosystems, define their feasible role, and act with 'enlightened self-interest' will be important in determining success or failure in a world of ecosystems. Such a concept does not disregard rivalry among European ports. It accepts, however, that competitiveness for big flows is carried out across rival cross-border supply chain ecosystems serving the same hinterland. Operational efficiency and dependability at the level of the regional port ecosystem, including its hinterland and short-sea routes, are critical for influencing the course of these enormous flows.

It is very pleasing to see that major ports around the world, such as Hamburg, Rotterdam, Singapore, Los Angeles, Qingdao and Busan, are deepening digitalization in port development and operation in order to improve port productivity and strengthen cooperation among stakeholders.[12] The smart port development strategies should be implemented in a continuous way in accordance with the existing port level and the existing level in stakeholder cooperation, based on a clear knowledge of the present port level and the definition of the future target level based on the outcome of the situation analysis.

Furthermore, the establishment of a smart port is to adapt to demand by integrating new technologies while making the most of the current system's information resources, and because it includes changes in the whole port ecosystem, a clear vision and constant management support are required. In addition to these conditions, one of the most essential elements is the engagement and collaboration of all stakeholders, since the support and involvement of port community members, including business sectors, is the foundation for further simplifying the transition to a smart port.

3.2 From optimizing silos to connected and transparent supply chains

At a smart port, digital solutions are placed around the physical layer as a "digital nervous system," constantly sensing what is going on in the port from several points of view: operational, safety, security, and environmental. Making port supply chains more transparent and linked is the foundation for inter-organizational operational performance and dependability. This progression will help foster confidence among port supply chain logistics providers and clients. This goal is theoretically feasible because of collaborative, open access data infrastructures and digital twinning of port infrastructure, operations, and business models. Yet, it also requires that actors take the responsibility to share data, to connect with community platforms across the port, corridor, or region, and to collaborate and co-invest in innovations that enable the benefits. However, it also necessitates those stakeholders accept responsibility for sharing data, connecting with community platforms throughout the port, corridor, or region, and collaborating and co-investing in technologies and innovative solutions that benefit them.

A big step towards transparent processes is represented by blockchain technology. Blockchain solutions can improve work productivity by exchanging real-time information (transportation information for inter-terminal transportation (ITT), container information, and so on) among port operations stakeholders. It

[12] The Economic and Social Commission for Asia and the Pacific (ESCAP): Smart Ports Development Polices in Asia and the Pacific, p. 10.

may improve transportation efficiency and yard operation efficiency, as well as reduce dispatch time, by employing the following services: grouped cargo allocation, block hauling, terminal information retrieval, and so on. Transparent transactions may substantially improve operational dependability.[13]

Blockchain provides several advantages, including increased dependability, lower potential costs, and shorter transaction times. Through transparent transactions and tracking features, it will be able to assure safety across the supply chain if blockchain technology is employed for port operations. To put it another way, port operations will be able to remove paperwork while also lowering the cost and time spent on resource conservation and port management. Nevertheless, it should not go unmentioned that many blockchain technologies are currently not a sustainable alternative due to the enormous power consumption caused by the computing power in the proof of work process. However, today there are already alternatives in blockchain technologies, such as the Proof of Stake process, which are much more environmentally friendly and sustainable because the computing power and thus the energy consumption is significantly lower.

3.3 From commoditized volume business to sustainability-driven innovation

Smart port business practices not only reflect the regional social, economic, and natural resource bases, but are also powered by innovations that embrace growing markets integrated within societal sustainability demands. The use of digitized freight data eliminates the need for needless physical movements. Improved synchronization of modes reduces emissions, travel time, and congestion. Circular solutions enable the monetization of one player's trash as raw material for another's operation. Ports, which are frequently seen to be on the opposing path of climate, globalization, or transportation concerns, may transform their profile via sustainable innovation. Because ports are mainly gateways to globalization, innovating and developing in sustainability and demonstrating ports' beneficial influence on society will have a favorable impact on the whole port community's license to operate.

Furthermore, the World Ports Sustainability Programme (WPSP), which was established by the International Association of Ports and Harbors (IAPH) in February 2019, aims to incorporate the Sustainable Development Goals (SDGs) into port authorities' business strategy and governance, as well as to assist aligning them with global sustainability standards. Environment and energy, community engagement and port city discourse, resilient infrastructure, governance and morals, and security and safety are the five topics of WSPS.

3.4 From ‘not invented here’ to a culture of collaborative and open innovation

Innovation in the port business process and the implementation of cutting-edge associated technologies are critical in defining the future for the development of a smart port. As a result, ports must focus on digitalized port operations and how to align the accessibility of Industry 4.0-based service platforms with the previous format. It is critical to introduce emerging technologies such as blockchain, artificial intelligence and machine learning, robots, and predictive analytic tools, and further standardization of port operations and related technology. Another critical necessity is the efficient collection of data.

The openness of smart port platforms for tech providers to build more solutions and business is driving the demand of smart port solutions and users. Acceptance is also a concern in interactions with port users, since global platforms must be able to deal with non-homogeneous maturity in terms of the

[13] Ibid.

technology utilized to receive, analyze, and share data. Moving towards smarter ports necessitates providing port users with varying levels of comprehensive information storage and sharing. The key challenge here is not a technical data exchange platform or an application programming interface (API), but rather increasing the digital and collaborative competence of the relevant stakeholders, as well as dealing with the huge aspect in the room, called trust.

Ports may be progressively integrating innovations throughout the value chain by employing a diverse variety of modern technology. As a result, the maritime transportation industry may be subjected to the effects of technological, commercial, and long-term issues. As a result, ports must increase their competence and productivity by implementing cutting-edge technology.

3.5 From ‘beggar-thy-neighbor’ to connected small and large hubs across corridors

In terms of data aggregation maturity, there are significant variations between ports and other supply chain nodes. While major ports are launching their own large-scale data gathering initiatives, shipping lines and downstream consumers want to be integrated with many of these smart port systems. It is a basic viewpoint to believe that certain information asymmetries should be utilized to push out the next participant in the chain, because the efficiency and reputation of the entire supply chain is what matters. Platforms with smart ports should enable for “further connectivity to any local platforms or stakeholders. This link will be a driving force in integrating the port's data with "satellite applications," making ports - that already have a community system - much smarter. It will increase competition for smaller ports that do not have their own Port Community System (PCS), Electronic Data Exchange (EDI), or other platforms by allowing access to user applications relevant and convenient to their stakeholders without requiring large expenditures in their very own data aggregation infrastructure.

An example is the European Maritime Single Window. Member States have set up a National Single Window through which shipping companies can submit information electronically and make this information available as necessary to multiple authorities. The European Maritime Safety Agency has been providing support to the member states, helping them to achieve a harmonized implementation and higher degree of digitalization. The purpose of the European Maritime Single Window (EMSW), as well as the Single European Transport Area (SETA) is to simplify and further harmonize the information procedures behind the various reporting obligations imposed on shipping companies through national, EU and international law.[14]

[14] European Maritime Safety Agency: European Maritime Single Window (EMSW). URL: http://www.emsa.europa.eu/emsw2.html.

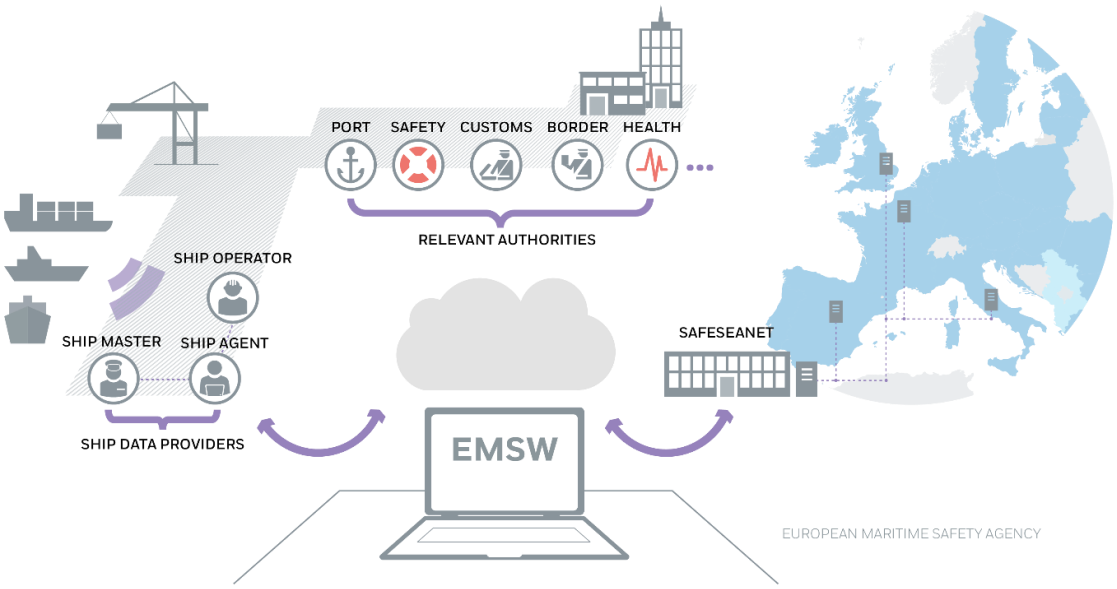

Figure 1: EU Maritime Single Window[15]

Beyond this, the National Single Window is another outstanding example for connecting small and large hubs across corridors in Germany. Since June 01, 2015, ship calls in German ports must be reported electronically via the Central Reporting Portal of the Federal Government. This concerns the arrival and departure of ships in or from a port in Germany as well as the transit of a ship through the Kiel Canal. The reporting obligation applies to ship owners, shipping companies, masters, agents, and their representatives. The national legal act is the Maritime Reporting Portal Act based on the European Directive 2010/65/EU. Electronic reporting via the national reporting portal brings advantages for all parties involved. The exchange of reporting information in paper form is no longer necessary and the data quality is improved by electronic reporting. Information that is required more than once only needs to be submitted once by the reporting party. The reported information is also transmitted more quickly to the respective authorities authorized to receive it. The reporting obligations are harmonized for port visits in all German ports and for transit voyages through the Kiel Canal, which further facilitates the exchange of data between the maritime industry and the competent authorities. Electronic reporting can be carried out via the recording module of the Central Reporting Portal.

This was implemented in German national law by amending the AnlBV (Anlaufbedingungsverordnung). The AnlBV is the basis for the obligation of shipping operators to report the information required by the ordinance electronically via the National Single Window Core System of the Federal Republic of Germany to the Federal Waterways and Shipping Administration in Koblenz. This is a communication between reporting parties and authorities. Communication with other commercial enterprises is excluded. Furthermore, DAKOSY, one of the leading software houses for logistics, operates the Port Community System (PCS) for the Port of Hamburg and the Cargo Community System (FAIR@Link) for airports. All companies and authorities involved in export and import processes can handle their transport processes quickly and automatically by using the digital platforms.

The obliged parties of an incoming or outgoing seagoing vessel transmit the data, such as the ship registration (port office), the list of crews (federal police) or the dangerous goods declaration (port office),

[15] Ibid.

to Advantage National Single Window (ANSW). A wide range of options are available for this. This information is transmitted to the NSW core system. The National Single Window ensures that every recipient, such as the Federal Police, the Port Authority, and the Maritime Health Authority, gets exactly the information they need. For this purpose, the data intended for you is made available to the authority via its own interface or a commissioned port information system (HIS).[16]

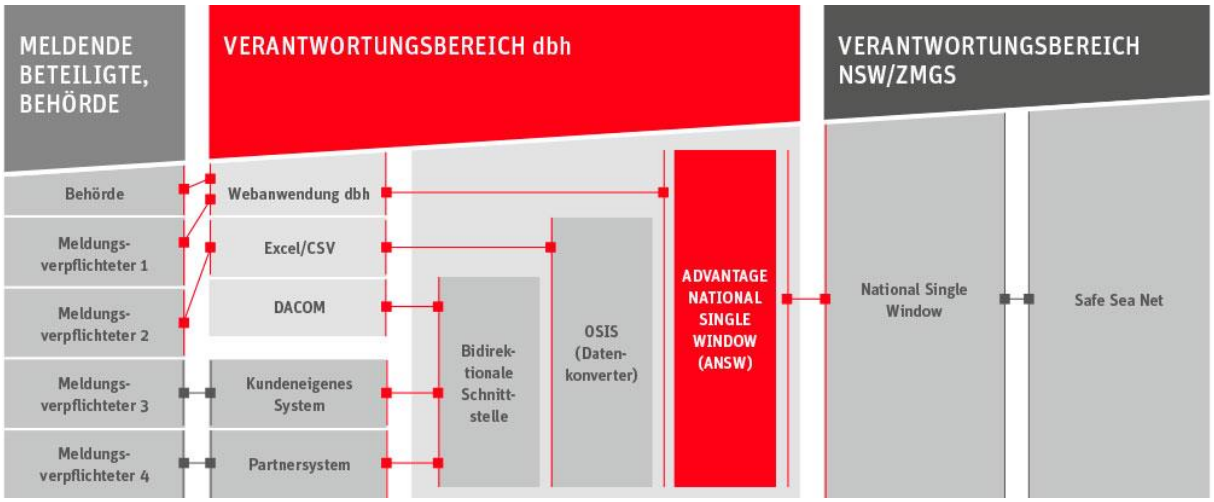

Figure 2: National Single Window[17]

3.6 From a closed to a market-driven and stakeholder-inclusive network

Port customers and technology suppliers must take the lead in terms of innovation and technology. Implementing innovation necessitates the concrete commitment of the whole supply chain that stands to gain. Smart ports can facilitate the sharing of thoughts among port users and technology suppliers while also establishing a shared communication with the other port stakeholders. By communicating port innovations to society stakeholders, port authorities may raise knowledge, comprehension, and interest in them. Local communities should recognize the work of port innovators to significantly enhance their reputation. Stakeholder in port cities should be as enthusiastic about the installation of a new innovative technology in their port as they are about a modern innovation in their mobile device.[18]

Smart ports are created by interconnecting a variety of information technologies and systems; they necessitate information integration, system convergence, and connection between individual systems, equipment, facilities, and business entities, along with cooperation and partnership among stakeholders, rather than just the use of advanced technologies. That affects their development difficulties owing to the present operating system's inertia, complex governance, and limited investment resources, among other issues. The amount and effectiveness of port informatization in member nations varies by country and port. As a result, through pilot projects and enhanced collaboration and partnerships with stakeholders, it is essential to identify the advantages, limitations, and dangers of on-site implementation of smart port technologies. Another essential aspect of smart port development is that it is not port-oriented, but rather connected and harmonized with the hinterland network. This connects them to a

[16] dbh: ANSW – Advantage National Single Window. URL: https://www.dbh.de/en/port-management/port-community-systems/answ-advantage-national-single-window/.
[17] Ibid.
[18] The Economic and Social Commission for Asia and the Pacific (ESCAP): Smart Ports Development Polices in Asia and the Pacific, p. 13.

wider goal of constructing an intermodal smart transportation network that integrates smart transportation plans and strategies by individual mode of transport to generate synergy and connectedness in the matter of mobility, efficiency, safety, and the environment.

Furthermore, it should be mentioned that because port logistics resources are related to each other via technologies such as IoT, Big data, and sensor networks, port operation efficiency will be substantially enhanced.[19] Another aspect that contributes to this is collecting and analyzing data created in real time which could be used for strategic planning.

3.7 From protective chain positions to customer-first ecosystem membership

Nowadays, the majority of smart port innovation inspirations come from stakeholders on the outskirts of/or even outside the supply chain. Making port supply chains smarter and more intelligent means using the strength of forward-thinking shippers. Furthermore, it is essential that digital start-ups are challenging and pushing the existing quo, data platforms pressing for integration and local or regional political as well as government pressure. Smart port stakeholders can discover innovation drivers in coordinated efforts targeted at enhancing value generation in the shared market (customers). This activity will enhance the overall potential value, which will then be divided among the launching parties. Before they can reap the benefits of smarter ports, port and logistics stakeholders will need to collaborate to produce scalable goods and services with an emphasis on collective competitive advantage.

Balancing out platform competition and collaboration, international and localized solutions, closed and open offerings and free market choice against regulatory oversight is a very difficult challenge, but not one that can be avoided if all the stakeholders want to reap the benefits of digital collaboration.

It is important to understand that ports that want to become smart need to use different technologies that automatically adapt and adjust to changing situations. Furthermore, it is essential to realize that actors like traditional companies, not only in the field of ports, who want to participate successfully in ecosystems, must often change the way how they think about customers.[20] Those Ecosystems attract more and more customers by providing products and services that individual companies could not generate on their own. This actually creates even more data, which allows artificial intelligence (AI) to form even better offerings, which in turn even farther helps to improve processes and ends up winning more customers. Ecosystems, by bridging gaps along the value chain, provide a customer-centric, unified value proposition in which customers may enjoy an end-to-end experience for a diverse variety of products and services via a single access gateway. Customers' costs fall along the way as they get new and unique experiences, whetting their desire for more.

3.8 From pipeline businesses to smarter network economics at a European level

Through network effects, digital platform tools may produce exponential top-line growth. Such network outgrowth can be recovered in conjunction with bottom-line scale and scope economies. Network economics creates an expanding variety of smart port applications for port customers while significantly lowering the development costs for more or less every application. This is especially valid if a platform once gains intensity. Developing a smarter network necessitates a vision that extends beyond the

[19] Ibid. p. 92.
[20] Chung, Violet/Dietz, Miklós/Rab, Istvan/ Townsend, Zac: Ecosystem 2.0: Climbing to the next level, in: McKinsey Digital. URL: https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/ecosystem-2-point-0-climbing-to-the-next-level.

present limitations. It is long past time to take serious efforts towards establishing a regional or European-scale data hub.

In this context, European states must establish a roadmap or strategy for smart ports and acquire the necessary funding and resources to support the transition. An important component of this work is an efficient approach of the port development level at the start of each project to create the best action plans for a smart port.

Therefore, a smart port roadmap is required at the national level, along with a complete study of the environmental program, such as vessel development trends, changes in the global economic system, the transshipment port, and the trade framework of the port's city. The European states should next develop a precise strategy and action plan, and an analysis of which innovations and technologies are applicable to smart ports.

Moreover, high-level leadership and close collaboration between both the government and the organizations involved are required. As European states confront resource restrictions as well as other challenges, such as a lack of competence and specialists for analytical or technical evaluation in developing a growth plan and transitioning to a smart port, specific analytical materials and an extensive capacity building program are required.

4 SMART PORT SOLUTIONS – EXAMPLES PORT OF HAMBURG

As everyone is seeking higher efficiency and better resource management, the digitalization of industrial processes is flipping the way of creating goods and services on its head. This is known as Industry 4.0, and the Internet of Things might be regarded its basic requirement due to the obvious necessity to collect data from all industrial assets.

The maritime industry is not an exception to this transition, which is accelerating. However, digitalization remains a largely untapped resource in ports: according to studies from February 2021, a whopping 80 percent of the world's 4,900 ports continue to rely on traditional and paper-based methods to administer maritime services.

For these reasons, the Port of Hamburg has set itself the task of making the port smarter, more digital, and more intelligent. The Hamburg Port Authority (HPA) is responsible for the targeted implementation of these measures.

Furthermore, interregional, cross-border and transnational cooperation plays a major role in the Hamburg Operational Program. The "Sustainable Logistics" measure establishes a link to the EU's INTERREG programs. Since 2019, Hamburg has been cooperating with the ports of Livorno, Nantes Saint-Nazaire, Monfalcone and Varna as a lead partner in the Low Carbon Economy project SMOOTH PORTS, which is funded by INTERREG Europe. - SMOOTH PORTS is about identifying approaches to solutions that can optimize the process flows of logistics operators in the port, reduce traffic and save CO2.[21]

Digital solutions play a major role in this. Within the framework of the "Sustainable Logistics" measure, these solutions can be implemented by interested logistics SMEs. The pick-up of project ideas for CO2 reduction and the exchange of experience with the Smooth Port partner ports are supported by the intermediary body. Synergies with the EU Baltic Sea Strategy are also expected. In this context, the

[21] EFRE-Programm Hamburg 2021-2027, p. 29.

2021 Action Plan in the policy area of transport provides for projects to "develop methods for climate-neutral [...] transport".[22]

Connections also exist with the just started Horizon2020 project MOVE21 (started in May 2021), which is working together with Oslo and Gothenburg to develop solutions for the last mile.

At the Port of Hamburg, state-of-the-art digital intelligence ensures smooth and efficient operations. The control systems used by the HPA are world leaders, and the interaction of sensor technology, analysis, forecasting and information systems has resulted in enormous efficiency gains. This is not only good for business, but it also protects the environment. And the digital trend ensures that the Port of Hamburg will maintain its leading position in Germany and Europe in the future. With the smartPORT philosophy, the Hamburg Port Authority is pushing for sustainable economic growth and the best possible benefits for its customers and the people of Hamburg, while minimizing the impact on the environment. And: smartPORT is constantly being developed and adapted.

With intelligent solutions for the flow of traffic and goods, the HPA increases the efficiency of the port. smartPORT logistics combines economic and ecological aspects in three sub-areas: Traffic flows, infrastructure, and goods flows. An intermodal Port Traffic Center for shipping, rail and road traffic forms the basis for networking traffic flows. Intelligent networking is a prerequisite for smooth and efficient traffic in the Port of Hamburg and, ultimately, for the flow of goods: Optimal data collection and a rapid exchange of information enable logisticians, freight forwarders and agents to select the most efficient mode of transport for the respective shipment.

The HPA also promotes environmentally friendly mobility and advocates reduced energy consumption. smartPORT energy helps reduce dependence on conventionally generated energy, cut emissions and save money. The focus is on three core areas: Renewable energy, energy efficiency and mobility.[23]

4.1 smartBridge

smartBRIDGE Hamburg is the ambitious project of a technology and civil engineering consortium commissioned by the Hamburg Port Authority. The question of this project is: How can the maintenance management of the aging Köhlbrand Bridge, landmark, and main artery of the Port of Hamburg, be optimized? The answer: digital transformation. The solution approach is made in the form of its Digital Twin, the Köhlbrand Bridge is brought to life to unite analog and digital condition data. More precise damage forecasts and thus predictive and sustainable maintenance management are the result.

Maintenance management encompasses all strategies, activities, and measures for maintaining or restoring a structure to a functional condition. What is required is a condition assessment that is as fit for the future as possible to optimize the allocation of resources in line with requirements. The goal: to extend the service life of structures. For infrastructures in particular, a modern maintenance strategy is the cornerstone of sustainable and smart maintenance management. Bridges, for example, are subject to their own aging process and an increasing volume of traffic and commerce. Depending on their location, there are also specific requirements for their smooth use. Bridges are subjected to increased stress. The effects can and should be counteracted with state-of-the-art technology.

[22] Ibid.
[23] Hamburg Port Authority: Energy Cooperation Port of Hamburg, p. 1 f.

smartBRIDGE is a pilot project with the aim of optimizing the maintenance of the Köhlbrand Bridge in the Port of Hamburg. The software creates a digital twin, a real-time representation of the real bridge based on all its available condition data, to improve its maintenance by all stakeholders involved.

With smartBRIDGE Hamburg as a real-time representation, maintenance manages the centralized analysis of all aggregated condition data of the Köhlbrand Bridge. Findings from cyclical structural inspections according to DIN 1076, diagnostic detailed examinations and continuous sensory monitoring are refined into condition indicators. Tons of heterogeneous raw data are given context; are meaningfully clustered and thus quickly usable. The classic structural inspection (interval cycle of three to six years) is by no means obsolete, but rather supported. Whereas building inspectors were previously only able to work reactively due to the long maintenance breaks, the networked IoT sensors enable them to better assess and even actively forecast degradation processes.

All these vital data converge in the Building Information Model (BIM), which stabilizes the growing information organism of the bridge's digital twin like a skeleton. All single sources of truth are contextualized spatially and semantically. Through networking, BIM becomes the clear node of the bundled data stream. The collaboration of all actors and the integration of their provided submodels is simplified. As a prototype, smartBRIDGE thus consistently extends the use of BIM and IoT to the utilization phase of the bridge. The Köhlbrand Bridge gets a pulse and even remotely.

A multi-level user interface provides intuitive scalable drill-down navigation for all stakeholders in smartBRIDGE. User-centric and easily consumable, the 3D software uses the open interface of the Open Geospatial Consortium (OGC) SensorThings API for data exchange. Via conditionCONTROL, users can choose from exploratory navigation within the geometric twin or guided tours through predefined menus. expertCONTROL provides insights into the raw data. In StructureVIEW, the viewer is almost immersed in the asset. The 360° view allows interactive inspections based on a photorealistic point cloud of the real surface structure, which is augmented with condition information. An effective tool! If you will, something like the digital stethoscope of the building inspector of the future.

smartBRIDGE Hamburg resolves the contradiction between complexity and applicability of highly differentiated condition indicators. The meta concept summarizes all data of the Köhlbrand Bridge and keeps them up to date. All involved actors can dock and their provided submodels can be integrated at any time. Asset management and maintenance can act even before damage occurs and affects both use and service life of the bridge. Condition forecasts become more accurate. Resources can be distributed in a more targeted manner. Prepared in an intuitive software, smartBRIDGE Hamburg sets a new benchmark in the digital transformation of bridge structure maintenance. A decisive step for the predictive maintenance management of structures all over the world![24]

Furthermore, the joint project by HPA, MKP, WTM Engineers, CustomQuake and CON+SCANTECH wins the Next Reality Contest 2021 in the category "Best Innovation". The Next Reality Contest is a German award for virtual reality/VR and augmented reality/AR applications.

4.2 Navigation in real-time

Thousands of trucks drive through the Port of Hamburg every day. To ensure that the traffic flows efficiently, the HPA combines various services and functions. Anyone driving around the port benefits from personalized navigation. As well as information about the traffic situation in and around the port,

[24] smartBRIDGE Haburg. URL: https://www.homeport.hamburg/portfolio/smartbridge.

they also have access to parking and infrastructure information, closures of the moveable bridges, as well as the latest information on important operations.

To implement all those aspects an Intermodal Port Traffic Center for shipping, rail, and road traffic serves as the foundation for future traffic flow networking and efficiency. To that purpose, all traffic data must be produced, analyzed, and disseminated to consumers. This will give road users and decision-makers with real-time information on the traffic situation at the Port of Hamburg, allowing them to select the quickest and most cost-effective method of transportation to deliver their products to their destination.[25]

Another digitalization project at the Port of Hamburg, launched by Hamburg Vessel Coordination Center (HVCC) together with maritime technology company Wärtsilä and cruise company Carnival, aims to ensure reliable ship arrivals, even more efficient ship handling and port logistics, and reduced fuel consumption and emissions. In the past year, HVCC has coordinated the arrival of over 3,200 ultra large container ships[26] in the Port of Hamburg. As part of this passage planning, HVCC determines the ideal arrival time (RTA Requested Time of Arrival) for a ship as it approaches the Elbe. In doing so, it considers factors such as berth occupancy, oncoming traffic, tide and weather conditions, and gets the operational overview approved by the relevant authorities – all this long before the ship begins its transit to Hamburg. The shipping company or ship management can use the RTA data to adjust the ship's speed and route to ensure that the vessel arrives right on time. This also allows terminals and other port service providers to make their plans at the same time. The resulting benefits of such a system are reliable arrival times, optimized port logistics and resource planning, and reductions in fuel consumption and emissions.[27]

Alongside the maritime technology provider Wärtsilä and cruise group Carnival, HVCC has now further developed its passage planning and has tested a one-of-a-kind, digital solution for just-in-time ship calls. For the first time the direct, real-time data exchange under real-world conditions between port and ship was realized to enable a dynamically optimized Hamburg approach.

The first live tests were carried out on the M/S "AIDAperla" and M/S "AIDAsol" – ships which regularly call at the Port of Hamburg. During these tests, the data shared between HVCC and Carnival Maritime's Fleet Operation Center in Hamburg was fed directly into the cruise ships' electronic nautical chart (ECDIS) via the Navi-Port digital platform developed by Wärtsilä. The continuous, dynamic, real-time data exchange improves coordination and allows for automatic modifications to a ship's course and speed should conditions at port change during a voyage. The innovative project is also being supported by the classification society Bureau Veritas to ensure that cybersecurity requirements are met. The team also includes the internationally renowned management consultancy HPC Hamburg Port Consulting with its expertise in port-side project management.[28]

4.3 Shore power from renewable energies

Thanks to a landside cruise liner power supply sourced from renewable energies, the Port of Hamburg is significantly reducing the environmental impact in Hamburg. These oceangoing giants are supplied

[25] Hamburg Port Authority: SMART-PORT – The intelligent Port. URL: https://www.hamburg-port-authority.de/en/hpa-360/smartport/.
[26] Ultra Large Container Ship is the generic name for container ships with a nominal container capacity of 10,000 TEU and over. (The Maritime Executive. URL: https://www.maritime-executive.com/editorials/snapshot-the-world-s-ultra-large-container-ship-fleet).
[27] Hamburger Hafen und Logistik AG: HVCC, Wärtsilä and Carnival achieve real-time data exchange between ship and port. URL: https://hhla.de/en/media/press-releases/detail-view/hvcc-waertsilae-and-carnival-achieve-real-time-data-exchange-between-ship-and-port.
[28] Ibid.

with electricity via a transformer station and mobile transfer mechanism. The dimensions of the landside power plant are unique in Europe. The Port of Hamburg is currently considering using similar models in other areas of the port in future. One great example for shore power from renewable energies is the shore power station at the Cruise Centre Altona in Hamburg. The shore power station, commissioned by HPA and realized by Siemens, was launched as a pilot project in 2016. As the station is unique in the world, a testing phase followed the launch, which lasted for more than one year. At the beginning of the 2017 cruise season, the station started regular operations. Since then, HPA has welcomed some expert delegations from around the world at the station, among them port authorities and terminals who wanted to learn more about Hamburg's shore power technology.[29]

In addition, there is a cooperation of seaports to reduce emissions from ships at berths. Five seaports in northwestern Europe have agreed to cooperate to make shipping more environmentally friendly. The aim is to supply large container ships in the ports of Rotterdam, Antwerp, Hamburg, and Bremen, as well as in the Haropa Ports (including Le Havre), with shore power by 2028 so that the ship's generators are not used when they are moored at the quay. Power is then supplied via a power grid cable. This benefits air quality and the climate, as less nitrogen and CO2 are emitted. The ports involved will coordinate their approach to shore-side power. The aim is to standardize, reduce costs and accelerate the use of shore-side power while maintaining equal conditions between the ports.[30]

The use of landside power supply is complex. For example, there is uncertainty about future (EU) policy on whether to mandate the use of landside power supply. International rules are needed to avoid worsening the competitive position of ports leading in sustainability. Investments in landside power supply are not readily available now: large investments in infrastructure are required, which are not possible without government support. In addition, there are so far few available solutions for providing landside power supply at busy quays. Currently, only a limited number of container ships are equipped with a landside power supply connection. Therefore, there are currently no terminals in Europe with landside power supply facilities for large container ships. After all, the current tax regulations for landside power supply are unfavorable: temporarily, no energy tax is paid for electricity; marine fuels are exempt from taxes in most ports.[31]

The provision of alternative power supply facilities for ships in the Port of Hamburg may mitigate the adverse effects. In a first step, shore power equipment for cruise ships to plug into while docked is to be installed at the terminal in Altona. In addition, a pilot project will be initiated to supply external power to container vessels as part of the "Green Shipping Line" between the ports of Hamburg and Shanghai. Hamburg's efforts are supported by the Federal Ministry of Transport, Building and Urban Development. The goals were already achieved by 2015 and has been the installation of a permanent shore power facility at the cruise ship terminal in Altona as well as the initiation of a pilot project to provide mobile electricity to cruise ships and external electricity to container vessels.

[29] Port of Hamburg: Shore Power Station at the Cruise Centre Altona in full Operation for one Year – Ship Calls soar. URL: https://www.hafen-hamburg.de/en/press/news/shore-power-station-at-the-cruise-centre-altona-in-full-operation-for-one-year-ship-calls-soar-35749/?.
[30] Port of Rotterdam: Seaports join forces to cut emissions from berthed vessels. URL: https://www.portofrotterdam.com/en/news-and-press-releases/seaports-join-forces-to-cut-emissions-from-berthed-vessels.
[31] Ibid.

4.4 Intelligent railway point

Frequently used points on the harbor railway are fitted with sensors that transmit data to a central IT system in real-time. They collect a variety of data by moving or passing over the switching points and thereby provide information about the condition and wear of the essential operational intersections. The benefit: Maintenance work or repairs can be identified at an early stage, thereby avoiding downtime.[32]

Under a pilot project, railway points located at critical points of the Port Railway's network has been equipped with multi-sensor technology. Supported by IT, the sensors centrally display the measured values captured whenever a point is switched or crossed. These data can then be used to predict wear and tear on the railway point. Moreover, heaviness of movement can be anticipated early on and addressed immediately. The operative management of the Port Railway thus is continually kept up to date on the condition of major points and can intervene in a timely manner and as required before disruptions occur. In addition, it is much easier for the Port Railway to plan maintenance measures.

4.5 The mobile all-purpose sensor

Where is the floating crane? Which emergency vehicle is closest to the incident? To be able to answer such questions, a mobile GPS sensor has been developed, which wirelessly forwards data to the HPA IT system. As well as intelligent fleet management, there is also use the sensor for other measurements, such as temperature, wind speed and direction, air pollution and the flow of the Elbe.[33]

The sensor is installed on or in the object and activated. As soon as it is activated, the sensor will transmit its position and ID to a central system that collects this information and provides it for further processing. This way, expensive equipment in the port such as, e.g., floating cranes can be located, the movement profiles of shunting locomotives can be recorded or the HPA's vehicle fleet can be managed more efficiently, including tracking of vehicles in the event of a disaster. On top of the GPS sensors, adapters can be installed that are fitted with additional sensors which measure, e.g., temperatures, wind forces, wind directions and air pollution levels or watertight sensors to measure flows in the River Elbe. If tracking of the allocated item is no longer necessary, the sensor can be de-installed and allocated to another object. The aim was to pilot-test a mobile multi-purpose sensor integrated in a road work traffic sign.

Furthermore, the Hamburg University of Technology, supported by the Hamburg Port Authority investigated aspects of miniature, low-power sensing, and actuating devices regarding energy supply from the environment (solar, wind, water flow, vibrations). In addition, they assessed the usage of low-power energy-harvesting sensors and actuators to integrate cyber-physical systems seamlessly into existing infrastructures. A central aspect was to optimize and schedule power consumption within the boundaries set by environmental energy and time aspects of the sensor values. Since satisfying all scheduling constraints on-the-fly is computational complex, they developed microcontroller-optimized algorithms to solve the underlying problems efficiently. Here, the main goal was to decrease potentially wasted energy, e.g., due to duplicate sensing or outdated sensor values, to increase the benefit for the operator of the sensor network.

Another example, which is good to mention here, is the PortMonitor as an innovative control station system for monitoring the Hamburg port area. The PortMonitor was developed in close cooperation with the Nautical Headquarters. This visualizes different sources of information such as ship movements, construction measures, applications and execution plans around different map displays. This provides

[32] Hamburg Port Authority: SMART-PORT – The intelligent Port. URL: https://www.hamburg-port-authority.de/en/hpa-360/smartport/.
[33] Ibid.

much better and more up-to-date support for decisions and communication about measures and their effects in port traffic. The integration of different existing systems facilitates handling and reduces errors in system use. Navigators and construction experts can concentrate on their actual tasks.

PortMonitor is tailored to the needs of the different user groups. The modern technology and architecture are the basis for a gradual and systematic expansion of the IT infrastructure in the port.[34]

4.6 Smart maintenance

The objective of this project was to check on site the road, bridge, and rail infrastructure in the Port of Hamburg, using mobile end devices such as tablet PCs or smartphones.

These devices communicate online with backend IT systems that process the data and create messages on the spot. The Hamburg Port Railway has already been using this technology for some of its infrastructure facilities as part of a pilot project.

When controlling roads, bridges and tracks, these devices automatically send measurements to the downstream IT systems, where the data is processed, stored, and edited. The aim is to make the maintenance processes more effective and efficient as well as to increase the quality of the messages.[35]

With reference to the PortMonitor explained in the previous section, the extension to include the mobile PortMonitor can be considered as a very positive example. Initially used as a desktop application, PortMonitor now also runs on mobile devices and a large video wall in the "nautical control center". The multi-device capability of the control station supports direct feedback between the navigators on the launches and in the nautical center. Current documents can be viewed on site. Changed or problematic situations can be photographed and directly forwarded to the control center. The map-based display of construction sites and measures enables situational route planning and changes.

This supports tasks of the control center "Nautical Headquarters" in the field, i.e., the employees on site are now included in the decisions and communication about measures and the effects in port traffic. This enables a direct response to important and potentially dangerous events.[36]

4.7 Virtual depot

In general, there is no direct communication between the process actors in container logistics, as the container fleet is controlled by the liner shipping companies and freight forwarders. In addition, the players often have no direct contractual relationship with each other. The liner shipping company, as the owner of the containers, has the containers packed and unpacked under its responsibility or leaves the empty boxes to the freight forwarder, who purchases these processes from the packing companies. After the full container has been unpacked at the packing plant, it is taken to an empty container depot. At a later point in time, this very same box is often moved again from the empty container depot to the same packing plant for use in seaborne export.

Due to the spatial distribution of the players in the port area and hinterland, this results in many truck journeys. This is where the "Virtual Depot" comes in. On the one hand, it enables supply and demand

[34] Workplace Solutions: PortMonitor. URL: https://www.wps.de/portfolio-items/portmonitor/.
[35] Hamburg Port Authority: SMART-PORT – The intelligent Port. URL: https://www.hamburg-port-authority.de/en/hpa-360/smartport/.
[36] Workplace Solutions: PortMonitor. URL: https://www.wps.de/portfolio-items/portmonitor/.

to meet in a virtual marketplace and, on the other hand, the processing and logging of transactions. In principle, the actual contractual relationships with all rights and obligations between shipowners, depots, packing stations, forwarders, truck drivers and other participants remain in place.[37]

According to estimates by the Hamburg Port Authority (HPA), more than one million trucks are on the roads in the Port of Hamburg each year with empty containers. Together with port companies and stakeholders, the HPA is developing concepts to improve logistics processes with the aim of further relieving the heavily used roads. As an important step, the Ministry of Economy and Innovation, the HPA and the Fachverband der Containerpackbetriebe e.V. (Trade Association of Container Packing Companies e.V) had the pilot project "Virtual Depot" implemented by the company IBM in 2016. The aim is to use an IT application to avoid unnecessary truck journeys in empty container logistics. Following a transparent bidding process, the HPA has now transferred the "Virtual Depot" project to the independent IT service provider DAKOSY and also concluded a cooperation agreement for the continued operation of the application. DAKOSY has integrated the project into its platform myboxplace.de. The platform will be used to broker empty container transports from seaport terminals to the hinterland / depots.

By December 2017, around 4,000 truck journeys in the port could be avoided with the help of the "Virtual Depot". This project thus makes an active contribution to improving air quality in Hamburg. DAKOSY maintains business relationships with many companies in the port as well as in the European hinterland and will now further develop the project. Accordingly, marketing and sales of the application can be done through these customer relationships.

"The great success of the Virtual Depot project is a good example of the Port of Hamburg being a pioneer in the field of digitalization," says Jens Meier, CEO of the HPA. "With DAKOSY, the HPA has now found a good partner who will further market and develop the application."

"By connecting the virtual depot to existing DAKOSY platforms for import and export processing, we expect additional synergies for all parties involved," says Ulrich Wrage, CEO of DAKOSY AG. "The aim is to integrate empty container handling as seamlessly as possible into the transport process as a result."[38]

4.8 Port Monitor

Since August 2012 the HPA has been using new control station software that was developed for the Port of Hamburg's Vessel Traffic Service Centre (VTS) under the Port Monitor pilot project.

The Port Monitors draws its information from various sources such as electronic charts, vessel positions, water levels, berths, bridge heights and widths, current construction sites, planned diving missions, etc. The information is retrieved from existing single systems and merged. Via links it can be called up directly from the Port Monitor.

In a second step the mobile app "Mobile Port Monitor" was added to the Port Monitor, whose data are now available on the tablet PC too. Information about construction sites and disruptions can now be processed on site on the tablet PC and transmitted to the VTS in real time.

[37] Hamburg Port Authority: Fewer trucks running empty in the port – HPA hands virtual depot project over to new operator. URL: https://www.hamburg-port-authority.de/en/press-latest-news/fewer-trucks-running-empty-in-the-port-hpa-hands-virtual-depot-project-over-to-new-operator.
[38] Ibid.

The control room software, Port Monitor, allows the HPA keep all the stakeholders in the port of Hamburg up to date. A variety of information is centrally gathered and can also be accessed remotely, such as electronic cards, vessel positions, water level data, berths, current construction sites, planned dives and bridge heights and widths. Important information is therefore always accessible to all those involved on land and on the water.

4.9 E-mobility in the port

In the medium term, studies will be undertaken to find out whether battery-powered and hydrogen-powered vehicles can be used in passenger terminal transport.

Electric vehicles are becoming increasingly commonplace in road transport. The HPA is also reviewing ways of extending e-Mobility to passenger and freight traffic in the harbor area. Therefore, the HPA is pressing ahead with charging infrastructure, in collaboration with the operators of public charging pillars. There is also a plan of using preferential e-Taxis at the cruise ship terminal. In addition, the terminal is analyzing the viability of e-Mobility for the staff.[39]

Talks will be held with port-based companies and associations to identify vehicles suitable to run on electric power and determine the feasibility of using them. The respective vehicles will then be retrofitted, and the electric vehicle charging station infrastructure will be expanded. In addition, it may be worth expanding the fleet of automatic guided vehicles and van carriers by vehicles running on alternative power or fuels. Where technically and operationally possible, the HPA's current vehicle fleet will be complemented by electric vehicles or replaced by vehicles that run on clean power. The goals are the retrofitting of other port-typical vehicle fleets to run on electric power and the provision of the required electric vehicle charging station infrastructure as well as the conversion of a portion of the HPA's vehicles to electric-powered or eco-friendly vehicles. Many of these goals have already been extensively achieved.

Furthermore, the Hamburger Hafen und Logistik AG (HHLA) and the truck manufacturer MAN Truck & Bus, which is part of the Volkswagen Group, are testing automated or autonomous trucks in real-life operations. The HHLA Container Terminal Altenwerder (CTA) serves as the test environment for part of the practical trials. "Hamburg TruckPilot" is the name of the highly innovative project for the development of automation solutions in road transport. The aim of the partnership is to analyze and validate under realistic conditions the precise requirements for customer-specific use and the integration of autonomously driving trucks in the automated container handling process. At the same time, forward-looking standards in methodology and implementation will be defined.

The prototype trucks, equipped with appropriate electronic automation systems, will handle unloading and loading fully automatically and autonomously within the CTA. Of course, a trained safety driver will always be in the vehicle to monitor the automation systems. If necessary, he will intervene and take over the driver's duties.

The automated driving functions are intended to relieve and support truck drivers in their work in the future. For example, the driver could leave the vehicle during autonomous loading and unloading and use the time for the legally required breaks. Further potential benefits lie in the increase in efficiency through predictive automated driving. This significantly reduces fuel consumption and can also have a

[39] Hamburg Port Authority: SMART-PORT – The intelligent Port. URL: https://www.hamburg-port-authority.de/en/hpa-360/smartport/.

positive impact on the general flow of traffic. Finally, the project partners expect an increase in safety in all areas.[40]

4.10 Parking for professionals

In view of the projected increase in trade, truck traffic and the demand for parking space are likely to grow too.

Always knowing where the nearest free parking space is and preferably reserving this, the Port of Hamburg aims to fulfil this requirement with the smart PORT logistics app for trucks. Its comprehensive parking management guarantees optimum utilization of existing and future truck parking spaces within the port. The system's features include the detection and management of parking spaces-, especially with a view to relieving the pressure in neighboring city districts.[41]

The HPA's comprehensive parking management system for heavy goods vehicles ensures that existing and still-to-be-built parking facilities for heavy goods vehicles in the port are optimally used, minimizing the number of trucks now parking in residential areas close to the port.

The mobile app of smartPORT logistics will inform truck drivers about capacities on the individual car parks and allow them to "book" parking bays. The parking space management system includes functions such as parking bay detection and parking bay administration and provides information about the availability of parking space, thus easing the burden on adjacent city districts. Dynamic parking space management in the port will be a valuable component of any future traffic management strategy. It will improve the utilization rates and cost-effectiveness of truck car parks, reduce the number of trucks looking for parking space, benefit the environment and ultimately make the Port of Hamburg more attractive.

4.11 Renewable energies

By focusing on innovative technologies, the HPA is adopting a pioneering role in Germany on the issue of a turnaround in energy policy. At the center of this is the efficient use and expansion of the existing networks, and above all options for generating renewable energies. The Port of Hamburg is currently reviewing wind and solar power and even bioenergy, because after all large quantities of bio-mass also accumulate in and around the harbor area.

Wind energy plays a central economic role for the whole of northern Germany and for Hamburg in particular. The Port of Hamburg can also be efficiently for energy production. The spatial proximity to the consumers saves transmission routes and therefore costs.

In addition, the numerous industrial and commercial halls in the port offer a lot of free roof space and thus great potential for the use of solar energy.

[40] Hamburger Hafen und Logistik AG: Rise of he machines. URL: https://hhla.de/en/magazine/rise-of-the-machines.
[41] Hamburg Port Authority: SMART-PORT – The intelligent Port. URL: https://www.hamburg-port-authority.de/en/hpa-360/smartport/.

Since green waste also accumulates a lot in and around the port area, e.g., on dikes and other lawns. Fermented into biogas, this previously unused biomass can replace fossil or conventional fuels.[42]

A variety of examples can be found in the Port of Hamburg, which are briefly explained below.

In the Port of Hamburg, more and more companies are installing their own wind turbines to generate their own energy. This is cheaper for port operations and increases their efficiency. The smart energy projects also show that renewable energies are economically competitive - and Hamburg is becoming a showcase for the German energy transition.

Q CELLS, a globally successful full-service provider of clean energy solutions in the fields of solar power systems, solar power plants, energy storage and electricity contracts, has implemented a photovoltaic system with Q.PEAK DUO solar modules for self-power supply in cooperation with the Hamburg-based company Nordic Solar GmbH. The 53 kWp system will produce more than 45,000 kWh of clean energy per year for the operation of the nautical headquarters and will additionally help to save more than 27 t of CO_2 annually. This system was installed on the roofs of the Nautical Headquarters in Hamburg, which covers a large part of the energy needs and noticeably reduces the operating costs of the Hamburg Port Authority.[43]

Another approach to renewable energy is to use gravel bricks in electrothermal energy storage systems to store electricity from renewable energy sources in the form of heat. This is the basis of an idea being researched by wind turbine manufacturer Siemens Gamesa, energy supplier Hamburg Energie and Hamburg Technical University. Since June 2019, they have been operating the ETES project in the Port of Hamburg. The acronym stands for Electro-Thermal Energy Storage. The project could help solve what is arguably the most serious problem facing renewable energy. For although the importance of wind and solar power in electricity generation is growing, these climate-friendly energy sources are by their very nature unpredictable. When there is a lull or dense cloud cover, for example, they do not supply any electricity - conventional power plants using gas and coal have to step in. And during stormy weather or on sunny summer days, renewable energies often cause an oversupply on the electricity market. Operators then must temporarily shut down their plant. Energy worth several hundred million euros is lost every year as a result.

In the test facility in the port of Hamburg, a kind of giant hair dryer heats the stones to up to 750 degrees. It takes a whole day for the silo to absorb its maximum capacity of 130 megawatt hours of thermal energy. Enough energy to supply up to 3,000 households with electricity for a day. For a week, the pile of stones can store the energy. As soon as it is needed, the heat is retrieved from the storage facility. It is used to generate steam, which eventually powers a turbine and generator. It is the same principle by which coal or gas-fired power plants generate electricity, except that instead of fossil fuels, hot air or renewable energy is used. However, this simple principle is not a zero-sum game. As with any other steam turbine process, more than half of the energy is lost in the electricity generation process. Nevertheless, Wulf Raether considers the ETES project to be an important contribution to the energy transition: "We are able to provide CO_2-free energy when the wind doesn't blow, or the sun doesn't shine." In addition, the storage facilities can absorb excess energy on stormy days, for example.[44]

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[42] Verkest, Marianne: Back to the future – Conference takeaways. URL: https://www.smartportsecosystem.com/test-pagina/b.
[43] Windkraft-Journal: Powered by Q CELLS: Nautische Zentrale Hamburg lenkt Schiffsverkehr im Hamburger Hafen mit der Kraft der Sonne. URL: https://www.windkraft-journal.de/2021/01/19/powered-by-q-cells-nautische-zentrale-hamburg-lenkt-schiffsverkehr-im-hamburger-hafen-mit-der-kraft-der-sonne/157383.
[44] Latz, Michael: Schottersteine speichern Windstrom im Hamburger Hafen, in: NDR. URL: https://www.ndr.de/nachrichten/info/Schottersteine-speichern-Windstrom-im-Hamburger-Hafen,fluessigerstrom100.html

Also, the HHLA contributes important successes in renewable energy solution approaches. Research and development work has begun on the FRESH sponsorship project at the HHLA Container Terminal Altenwerder (CTA). The goal is to integrate the battery capacities of the automated guided container transport vehicles (AGVs) that are in use at CTA into the German energy network as flexible storage units that contribute to the grid stability of the power supply. Together with Next Kraftwerke, the computer science institute OFFIS in Oldenburg and the University of Göttingen, HHLA is developing a process and software solution for electricity market access as part of the three-year FRESH project. The project, which is being supported by the German Federal Ministry for Economic Affairs and Energy as part of the "ICT for Electromobility III" technology program with funding of approximately 1.4 million euros, is designed to digitally manage the requirements of virtual power plant and trouble-free terminal operation.[45]

5 SMART PORT SOLUTIONS – EXAMPLES FROM THE NSR

As part of a survey on Smart Port Solutions among all participating project partners, several interesting examples were highlighted, which will be discussed in more detail below.

A Smart Port Solution that has been included by Vordingborg Erhvervsnyt is *Waste App* developed by Wasteland Technology ApS in Silkeborg, Denmark. Waste app is currently already on the market and in operation. Waste App is an application used in the field of waste management. It can be installed on all kinds of smartphones and ensures smooth and revenue-oriented waste disposal through quick and easy ordering with just a few clicks. The app offers the customer the possibility to have the complete overview and documentation of all waste transports digitally always available and to coordinate them. A major problem in waste disposal that Waste App is trying to fix is that many containers have been emptied on a weekly basis, regardless of whether they have been full or only half full, for example. Through the app, communication between the end customer and the waste management company is very simple, so that optimization of waste management is easy to achieve. There are hidden time and money savings in waste management that can be generated by an intelligent and digital disposal concept such as Waste App. This can be achieved, for example, by avoiding the situation where only half-full waste containers are collected from the customer and a collection only takes place when the need is identified by the customer and released in the app.

Another project example from the North Sea Region is the *NON-STOP* project, which stands for New smart digital Operations Needed for a Sustainable Transition of Ports. The project has been running since July 2019 and is active until the end of 2022.

The NON-STOP project addresses the possibilities of digitalization for small and medium-sized ports in the North Sea Region, which have to face increasingly complex and rapidly changing requirements. A more efficient, agile, and transparent data management between small and medium-sized enterprises, shipping companies, freight forwarders and other relevant stakeholders leads to a customer-effective interaction and creates incentives to invest in further, necessary innovations. With a focus on ports labor/time, energy and pollution reduction the partners will develop innovative digitalized information management systems in ports to achieve higher performance and time/energy/pollution reduction, considering interoperability and interconnectivity requirements and test the designed smart sensor-based/digitalized technologies in NON-STOP ports. Furthermore, With a focus on sea/port/land-side

[45] HHLA: The FRESH project – container transporters as mobile power stores? URL: https://hhla.de/en/company/innovation/research-and-funding/fresh.

management, the partners will elaborate and pilot digitalized management technologies that allow enhanced use/monitoring/control of (bio) energy use and smart digital programs for the management and valorization of port areas/assets with energy/time reduction and select port human resources with the specific task of fostering the design and implementation of digitalization strategies and exchange of information on intelligent technologies within the NON STOP partnership and triggering further port digitalization process within the NSR.

Centered on a ports smart digitalization program, the whole partnership has specialized in developing a scientifically sound tool to assess & validate the testing and use of the piloted innovative environmentally friendly digital technologies and processes in port management, also in relation to their industrial partners (NON STOP tool to calculate time/energy/pollution reduction for the demonstrators);In addition they want to evaluate the pilots via the created tool and share data with local communities and transnational stakeholders. Also, one last goal is to produce a NON-STOP green digital ports strategy with recommendations for other NSP ports on the different uses of technologies for smart port management to drive digital transformation. The strategy should meet the objectives of the UN “Global clean Ports” program, EC & North Sea countries Digital Agendas.[46]

Another example of various Smart Port solutions is the information system *PRISE* from the Port of Hamburg. PRISE is a globally unique information platform on all ship arrivals and departures in the Port of Hamburg. It is specially tailored to the needs of the Port of Hamburg and is being further developed by DAKOSY on behalf of the HVCC Hamburg Vessel Coordination Center. It provides the terminals, pilots, shipowners/brokers, tugboats, mooring companies and the Oberhafenamt with a wealth of up-to-date information. The data provided includes berth planning and registration of the terminals, status information on ship positions on the Elbe from "German Bight" to "Leinen fest", ship registrations of the Elbe pilots, responsibility reports of the tugs and mooring companies, and water level forecasts of the Federal Maritime and Hydrographic Agency (BSH). Only by accessing this wealth of information can the parties involved cope with the increasing complexity of planning and executing the growing number of large container ship handling operations. Thanks to PRISE, it has been possible to improve the plannability of the shipping lane on the Elbe as well as ship movements in the port, and to accelerate the overall flow of traffic.[47] Moreover, the worldwide unique software is further developed in consortium with HVCC and HPC.

Furthermore, the Port of Antwerp is another example of the North Sea Region trying to develop efficient Smart Port solutions and implement them effectively. Jacques Vandermeiren, CEO Port of Antwerp-Bruges, says that the “Port of Antwerp-Bruges is aiming to build a digital nervous system to fully manage the port remotely. By working with innovative partners and opening up the port as an innovation platform, we are making our port smarter, safer and more efficient.”

Port of Antwerp is considered to be a so-called NxtPort. The basic objective of NxtPort is to enable data sharing among users of the port. The NxtPort Data Utility Platform enables quicker, more affordable, and more effective data transfers between the various parties. The platform increases shipping process transparency overall. NxtPort wants to boost operational effectiveness, security, and income.

Allowing market applications to be built on top of the current data is a second way to unlock the enormous value at stake. In this manner, the data within the port is not only better exchanged, but the

[46] NON-Stop Project: URL: https://northsearegion.eu/non-stop/non-stop-project-structure/.
[47] DAKOSY: PRISE - Port River Information System Elbe. URL: https://www.dakosy.de/en/solutions/cargo-communications/port-community-system/prise.

integration of the existing data will also result in creative ideas. For the Port Community and its individual participants, they generate new business and new revenue streams.[48]

The supply chain becomes more transparent when all stakeholders have access to timely, accurate, and comprehensive datasets, which is a critical enabler for increased operational effectiveness, resilience, safety, and sustainability. Through a cutting-edge data sharing platform where data governance fosters trust, we link all data suppliers. We broaden our horizons as a facilitator for open data from port community systems in support of the global supply chain.[49]

Each participant in the logistics chain shares information with the others. The Port of Antwerp-Bruges subsidiary NxtPort facilitates and improves data sharing. By doing this, every link in the logistics chain receives the appropriate information at the appropriate moment.

The Certified Pick up (CPu) program offers a digital, safe, integrated solution for the release of containers, while the Bulkchain application makes sure that administrative procedures in the breakbulk industry operate more quickly and efficiently.[50]

Furthermore, The Port of Amsterdam, as a North Sea port, is also constantly looking for new smart port solutions. In the last months, Port of Amsterdam has been replacing all existing shore power units with smart, green shore power. This has happened to all cabinets in the port area within the ring of Amsterdam.

The new shore power cabinets are much more intelligent and user-friendly than the older models. For instance, you can use the Park-line app to control them while specifying how much electricity you require. You plug in the box and gain access to shore power after entering a code. You always pay for the exact quantity of power used because the software measures usage so precisely. Through the app, payments are also made.

Engineers can also fix any problems more quickly. The smart boxes identify issues right away. For instance, they keep track of the power consumption and whether a secure connection is there. The boxes alert the engineers if there is a problem. They can then quickly identify which shore power box is the issue.

Additionally, remote control of the cabinets is possible, for instance by resetting the earth leakage switch. As a result, it will no longer be necessary for the engineers to travel to the malfunctioning area, saving them both time and aggravation. However, these were not the main reasons for choosing the new shore-based power, says Steve Faerber, head of Asset Management and Projects. "The ambition of Port of Amsterdam is to encourage and facilitate clean shipping in order to create a sustainable port. The new shore power cabinets fit perfectly into this strategy. They reduce CO_2 emissions because ships no longer need to use generators. The cabinets also produce green electricity. In addition, they reduce the noise and odor nuisance for local residents."[51]

[48] NxtPort: URL. https://www.nxtport.com/en/about.
[49] Ibid.
[50] Port of Antwerp Bruges: Smart Port. Url: https://www.portofantwerpbruges.com/en/our-port/port-future/smart-port#nxtport.
[51] Port of Amsterdam: Port of Amsterdam installs new smart shore power cabinets. URL: https://www.portofamsterdam.com/en/news/port-amsterdam-installs-new-smart-shore-power-cabinets.

6 SMART PORT SOLUTIONS – EXAMPLES FROM OTHER EU REGIONS AND PROJECTS

Today's ports are constantly surrounded with operational data such as resource tracking, vessel operations, berth services, marine litter/pollution measures, and so on. Capabilities now in use are insufficient to meet the aforementioned needs. Due to limited space and high costs, several ports have chosen to incorporate innovative, low-cost, widely available smart technologies rather than expand their infrastructure. Ports can efficiently handle operational data in this manner, generating new useful information that will serve as the foundation for handling new issues.

Many ports are interested in an enhanced port model known as smart port, which employs IoT-based communication infrastructure. The following chapter will provide an overview and evolution of some of the best smart port ideas in the European Union, as well as their major benefits and values. In addition, the concept of a complicated link between the port and the city itself will be investigated and analyzed.

An example of a project based on Smart Port Solution is the **COREALIS** project launched in 2018. The project ran until April 2021 and was funded by Horizon 2020. COREALIS proposed a strategic, innovative framework, supported by disruptive technologies, including IoT, data analytics, next generation traffic management and emerging 5G networks, for cargo ports to handle upcoming and future capacity, traffic, efficiency, and environmental challenges. The proposed beyond state-of-the-art innovations, targeted to increase efficiency and optimize land use, while being financially viable, respecting circular economy principles and being of service to the urban environment.

The innovations were being implemented and tested in real operating conditions in 5 Living Labs, namely Piraeus port, Valencia port, Antwerp port, Livorno port and Haminakotka port, and are briefly presented in the figure below:

Figure 3: COREALIS operating conditions[52]

[52] COREALIS project. URL: https://www.corealis.eu/#about.

There were some essential port-driven technological and societal innovations that were tailored to realize COREALIS high level objectives, which are focused on:

- Embracing circular economy models in its port strategy and operations.
- Reducing the port's total environmental footprint associated with intermodal connections and the surrounding urban environment for three major transport modes, road/truck, rail, and inland waterways.
- Improving operational efficiency, optimizing yard capacity, and streamlining cargo flows without additional infrastructural investments.
- Enabling the port to take informed medium-term and long-term strategic decisions and become an innovation hub of the local urban space.

The aforementioned objectives were fulfilled through the implementation of a 3-step 'Stakeholder driven approach' methodology, which starts with the identification of port requirements (technical, operational, societal, environmental, legal, security etc.) (Phase 1), it continues with the technical design and development of COREALIS innovations (Phase 2), and it ends up with COREALIS Innovations Impact Assessment and Living Labs (LLs) full-scale implementation (Phase 3).[53]

Another example of a smart port-based project is the **PIXEL** project. Pixel is dealing with the question on where IoT meets the Port of The Future. The project stared in May 2018 and ran until the end of September 2021. Just like COREALIS, PIXEL was also created with the funding of HORIZON 2020. PIXEL will enable a two-way collaboration of ports, multimodal transport agents and cities for optimal use of internal and external resources, sustainable economic growth, and environmental impact mitigation, towards the Ports of the Future. PIXEL will leverage technological enablers to voluntary exchange data among ports and stakeholders, thus ensuring a measurable benefit in this process. The main outcome of this technology will be efficient use of resources in ports, sustainable development and green growth of ports and surrounding cities/regions.

Built on top of the state-of-the art interoperability technologies, PIXEL will centralize data from the different information silos where internal and external stakeholders store their operational information.

The PIXEL project team believes that the Port of the Future concept does not reflect only a future of large European ports, but also of the medium and small ones. Moreover, the PIXEL partners are fully aware of the current diversity and heterogeneity of this kind of ports caused by port size but also by their internal organization resulting in a remarkable gap in small and medium port capacity to move on to the port of the future. Therefore, PIXEL advocates for a Port of the Future concept structured into two levels:

- The level of **current and emerging requirements placed upon all ports** (e.g., requirements due to competition, environmental, governance, and other issues)

- The level of **implementation of the Port of the Future concept**, which must be based on a realistic assessment of the current capabilities of the different sizes of ports, and more importantly on the opportunities for enhancing those capabilities through the employment of technological, managerial, and scientific approaches.

Furthermore, since economic, environmental, and social sustainability are intertwined, all three must be achieved for their impact to be sustained. Therefore, while PIXEL is mainly focusing on the environmental sustainability of ports, it also aims at enhancing their economic and social sustainability.

[53] Ibid.

The size of a port, and its corresponding financial and organizational resources, are often assumed as the main prerequisites for a port to be capable of introducing innovation and achieving a significant reduction of its environmental impact. According to this assumption, medium and small ports are destined to be followers in terms of environmental initiatives, innovation, and impact. In contrast to this, PIXEL is implemented on the principle that, regardless of the size of the port, it is possible for a port with limited resources (i.e., a medium and small port) to significantly minimize its environmental impacts by relying on scientific methods and innovative technologies.[54]

Not only single projects related to Smart Port Solutions are currently on the rise, but even entire ports are showing tremendous progress in the implementation of entire sustainable and intelligent Smart Port strategies.

The Port of Barcelona is a forerunner in the use of technical solutions in the commercial, public, and logistical sectors. The focus is to achieve efficient and transparent solutions that provide value to the end customer while extending the company's responsibility to the environment and providing excellent places and services to the general public.[55] As a constantly innovating port and a pioneer Smart Port, the Port of Barcelona is continuously trying to bring innovative solutions to make life simpler for consumers and companies. Barcelona's port has created its own Smart Port model based on the Smart City academic model, which includes six major transformation elements tailored to the port environment: logistics, mobility, the environment, economy, people, and governance. The model with its components is made of several parts, which can be identified in the figure below.

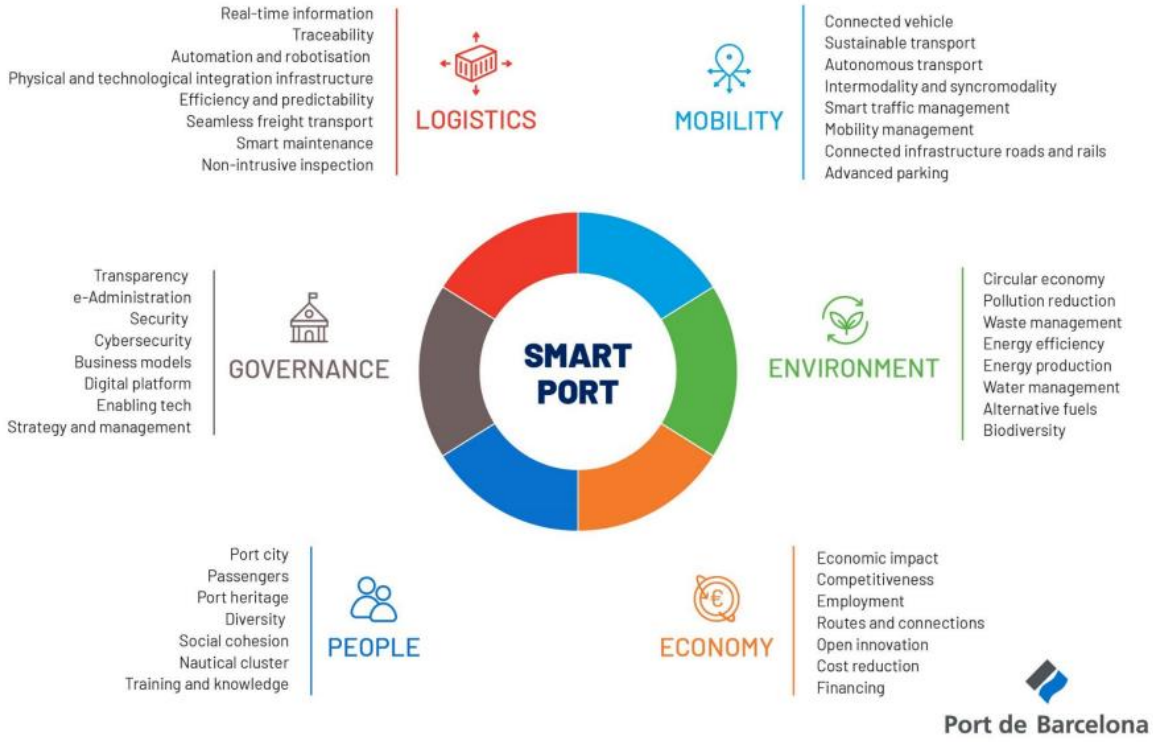

Figure 4: Port of Barcelona[56]

[54] https://pixel-ports.eu/?page_id=330.
[55] The Smart City Journal: Barcelona, a Smart Port that is constantly innovating. URL: https://www.thesmartcityjournal.com/en/cities/barcelona-a-smart-port-that-is-constantly-innovating.
[56] Torrent, Jordi: The Smart Port model at the Port of Barcelona. URL: https://portalcip.org/wp-content/uploads/2019/04/16_30_18_05_1_JORDI_TOREENT.pdf.

Implementing the Smart Port concept has therefore represented and continues to reflect a series of problems faced by the port, which can be classified into the five categories mentioned below.

1. “Cybersecurity. According to Lance Kaneshiro, CIO of the Port of Los Angeles, “All of the port stakeholders are going to start generating and sharing a lot more data in different places. This data now comes in a variety of formats. We need to standardize these formats so the data can flow between different ports and platforms. Digitalization processes will lead to increase in our cybersecurity needs, which must be handled not only on individual level but also a system, as part of a series of interconnected networks.”
2. Application based on Big Data. Data analysis in conjunction with deep learning can lead us to create predictive, prescriptive systems that anticipate responses and incidents and help interest groups with decision-making.
3. Blockchain. This will help develop smart self-executing contracts that are safer and more reliable, i.e., an automated process to exchange goods or services between companies.
4. Geographic information systems with value-added. Developing systems based on geolocation could help speed up process and change the port dynamic: from detailed monitoring of cargo status to the option to oversee vehicles, allowing certain tasks to be automated.
5. Traffic management systems. Gate Appointment Systems (GAS) have been the response many port authorities have used to address this issue, to remedy the negative side effects of intermodal transport around ports, as containers are constantly entering and leaving the terminals, which can generate congestion and traffic jams.”[57]

7 RECOMMENDATIONS AND CONCLUSIONS

After a detailed theoretical introduction to the topic and classification of the problem in the context of smart port solutions of what is happening within the NSR, the principles for the logic of a smart innovation ecosystem were examined in more detail in the further course.

It was identified that major ports around the world, such as Hamburg, Rotterdam, Singapore, Los Angeles, Qingdao, and Busan, are deepening digitalization in port development and operation in order to improve port productivity and strengthen cooperation among stakeholders.

Furthermore, regarding the change from optimized silos to connected and transparent supply chains, making port supply chains more transparent and linked is the foundation for inter-organizational operational performance and dependability. This progression will help foster confidence among port supply chain logistics providers and clients.

In addition, smart port business practices not only reflect the regional social, economic, and natural resource bases, but are also powered by innovations that embrace growing markets integrated within societal sustainability demands.

With reference to collaborative and open innovation was discovered that innovations in the port business process and the implementation of cutting-edge associated technologies are critical in defining the future for the development of a smart port. As a result, ports must focus on digitalized port operations and how to align the accessibility of Industry 4.0-based service platforms with the previous format.

[57] Emma Cobos: Port of Barcelona: Ports and cities come together under the smart concept, p. 14. URL: https://wpassets.porttechnology.org/wp-content/uploads/2020/09/29144822/PTI_100-HR_014-015-1.pdf.

In terms of data aggregation maturity, there are significant variations between ports and other supply chain nodes. While major ports are launching their own large-scale data gathering initiatives, shipping lines and downstream consumers want to be integrated with many of these smart port systems.

Moreover, it is of crucial importance port stakeholders as collaborative community must take the lead in terms of innovation and technology. Implementing innovation necessitates the concrete commitment of the whole supply chain that stands to gain. Smart ports can facilitate the sharing of thoughts among port users and technology suppliers while also establishing a shared communication with the other port stakeholders.

Also, to build a customer-first ecosystem membership it is important that smart port stakeholders discover innovation drivers in coordinated efforts targeted at enhancing value generation in the shared market (customers). This activity will enhance the overall potential value, which will then be divided among the launching parties. Before they can reap the benefits of smarter ports, port and logistics stakeholders will need to collaborate to produce scalable goods and services with an emphasis on collective competitive advantage.

Additionally, through network effects, digital platform tools may produce exponential top-line growth. Such network outgrowth can be recovered in conjunction with bottom-line scale and scope economies. Network economics creates an expanding variety of smart port applications for port customers while significantly lowering the development costs for every application. This is especially valid if a platform once gains intensity. Developing a smarter network necessitates a vision that extends beyond the present limitations. It is long past time to take serious efforts towards establishing a regional or European-scale data hub.

The principles towards a smart innovation ecosystem logic were followed by a look at various solution-oriented approaches that have been implemented at the Port of Hamburg to make the port smarter and more digital, thereby making operations more efficient, more precise, and intelligent. The solutions have already been discussed in detail in the fourth chapter, which is why they are only briefly discussed again here.

- smartBridge Hamburg
- Navigation in real time
- Shore power from renewable energies
- Intelligent railway point
- Mobile all-purpose sensor
- Smart maintenance
- Virtual depot
- Port Monitor
- E-mobility in the port
- Parking space management
- Renewable energies

Of course, some exemplary projects and solutions can also be found in the NSR that make their contribution to Smart Ports. A Smart Port Solution that has been included by Vordingborg Erhvervsnyt is *Waste App* developed by Wasteland Technology ApS in Silkeborg, Denmark. Waste App is an application used in the field of waste management. It can be installed on all kinds of mobile devices and ensures smooth and revenue-oriented waste disposal through quick and easy ordering with just a few clicks. The app offers the customer the possibility to have the complete overview and documentation of all waste transports digitally always available and to coordinate them

Another project example from the North Sea Region is the *NON-STOP* project, which stands for New smart digital Operations Needed for a Sustainable Transition of Ports. The NON-STOP project addresses the possibilities of digitalization for small and medium-sized ports in the North Sea Region. which must face increasingly complex and rapidly changing requirements.

Another outstanding example of various Smart Port solutions is the information system *PRISE* from the Port of Hamburg. PRISE is a globally unique information platform on all ship arrivals and departures in the Port of Hamburg.

Not only in the NSR, but also other EU regions are showing themselves to be very pioneering in terms of smart port solutions with a wide variety of projects. In this respect, for example, the Horizon 2020 project, implemented by Piraeus port, Valencia port, Antwerp port, Livorno port and Haminakotka port, stands COREALIS out. It proposed a strategic, innovative framework, supported by disruptive technologies, including Internet of Things (IoT), data analytics, next generation traffic management and emerging 5G networks, for cargo ports to handle upcoming and future capacity, traffic, efficiency, and environmental challenges.

Furthermore, another Horizon 2020 project, PIXEL, was implemented in the year of 2018. As already mentioned in the last chapter the project is dealing with the question on where IoT meets the Port of The Future. Additionally, it will enable a two-way collaboration of ports, multimodal transport agents and cities for optimal use of internal and external resources, sustainable economic growth, and environmental impact mitigation, towards the Ports of the Future.

The report shows that there are not only individual projects aiming at smart, digital and intelligent ports, but that entire ports are trying to implement such smart port concepts as a whole.

All in all, it can be said that there are many approaches, projects and ideas that pursue and implement the smart port concept. Implementing such concepts is affected by several different problems which the ports are trying to solve, not only on its own, but also in cooperation with other ports.

Without a doubt, the notion of smart ports is not the final stage in the evolution of seaports. The ongoing introduction and implementation of the idea of smart ports is an irreversible trend that affects the growth path of modern seaports. Ports, on the other hand, need time to grow in terms of intelligence. It is also critical to provide clear indications and metrics for port intelligence. Individual creative actions cannot be regarded as applying the smart port idea. It is vital to establish tight framework criteria as well as particular instruments.

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