Connect2SmallPorts

within the frame of the South Baltic Programme

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1. Introduction

In recent discourses, digital technologies, such as safe and secure distributed databases – block-chain – and other so-called data-enabled technologies have been on the top agendas in policy, business and academic research. They are already distributed in industry sectors, such as manufacturing, IT as well as transport and logistics (e.g. [1] – [6]). Principally, these technologies are not new. In recent decades, there have been much of discussion on automation, safe and secure operations and traceability. What is new, this is more condensed focus on these technologies in the face of rapid globalisation and integration, increasing environmental and competitive pressure, rapid responsiveness to customers and clients' needs.

This is a right time, a decade, where heavy discussions on digitalisation have pushed forward interest in and focus on more state-of-the-art technologies that generate both, monetary and strategic value for business stakeholders and merge to digital networks and platforms, enabled through Internet of Things (IoT) and/or Industry 4.0. In order to capture the rapid pace of change induced by such digital technologies, ports as gateways of economic and social interactions for regional development and growth must also take a substantial action now. The addressed situation will extremely affect maritime and inland ports. Harsh environmental, competitive and operational pressures are expected in small and medium-sized ports that partly build up the so-called comprehensive TEN-T Network [7]. 66% of all Baltic Sea Region (BSR) ports are small and medium sized ports (so-called comprehensive ports or non-TEN-T ports). Their total cargo turnover amounts less than 2 million tonnes per year [8].

Small ports, especially located in the South Baltic Sea Region (SBSR) suffer from less freight volumes, missing smart specialisation, out-dated infrastructure, investments and new business models contributing to blue and green growth. Furthermore, compared with their bigger counterparts, they receive only minor financial support from the EU. This situation exercises even more pressure on them, when considering access to and utilisation of digital technologies. In the increasing digitalisation age, their bigger counterparts – core ports according to the analogy of the TEN-T – are already heavily investing in industrial digitalisation, since they have acknowledged strategically the added value from digitalisation. Yet, smaller ports have no or limited knowledge on what Industry 4.0, Internet of Things (IoT), blockchain are and what potentials they have for the ports. Smaller ports often do not know about the already existing wide range of ICT solutions and current trends that allow optimising the infrastructure and transport services and solutions [7].

Bearing this challenging picture, this research report addresses the gap of a marginalised focus laid in the research on smaller players, such as small and medium-sized ports. It builds on arguing that smaller, weaker or regionally bound stakeholders in the SBSR could also benefit from evolving digital networks and use of digital technologies for innovation, value creation and competitiveness next to their bigger counterparts. The research was conducted in the frame of the project "Connect2SmallPorts", which was kick-started in the second half of 2018 and is implemented in the cross-border cooperation platform INTERREG South Baltic Programme 2014-2020. As a result, this report develops the so-called digital auditing procedures and digital auditing tool that will be applied in the involved regional ports. By doing this, the authors utilise innovative approach and combine theoretical concepts and practical insights residing in different management fields – auditing means that are frequently emerging and addressed in discourses on open innovation, service design as well as performance parameters and theoretical foundations pertaining to supply and value chains, clusters and transport corridors' management. Therefore, this report yields both theoretical and practical contributions, where the affected actors themselves can test and utilise the developed tool.

The report is structured as follow: In the second chapter, the methodology is set out. Afterwards, in chapter three, the state of the art of digital technologies in ports is drawn by referring to some best practice examples from top players in the industry as well as the current situation of ports that are located in SBSR. Subsequently, in the course of chapter four, the cross-border digital auditing tool for small ports is developed and presented. Thereby, firstly, the needed theoretical background is exhibited for the theory and target-oriented choice of direction for the development of the digital auditing tool. This is followed by highlighting the results from the conducted literature review and thus, the developed concept is described, which bases on a qualitative approach for measuring the digital performance and digital readiness of ports. In the frame of the fifth chapter, the initial presented digital auditing tool from chapter four, is extended by a quantitative component part for measuring the operating performance of ports. In the latter case, this extension is important, since the incorporation eases the aspired and future benchmarking of the ports in the frame of classification. Building upon this, in the sixth chapter, the cross-border digital auditing tool application procedure is developed and described. The report rounds up with a discussion and conclusion.

2. Methodology

The theory-based and practical findings demonstrated in this study report have been originally collected and produced in the course of the project "Connect2SmallPorts". This research project is implemented in the INTERREG VA South Baltic Programme. Among other things, the EU-project focus on improving cross-border connectivity for a functional blue and green transport area, with the objective to enhance the quality and environmental sustainability of transport services in the South Baltic Sea Region. The majority of the presented results of this study report base on a wide desk research and an extensive literature review, whereby the identified relevant literature was analysed and further synthesised. Apart from the systematic literature review, analysis and study of relevant theories and concepts, relevant policy regulations and guidelines, the research findings demonstrated here also base on qualitative data that had been collected directly by the authors in the frame of qualitative expert interviews with project target groups. In addition, the applicability of the received and elaborated research findings (here especially: digital auditing tool) have been validated and verified by the main target groups during practical workshops and targeted seminars. The main target groups include: policy makers and port authorities that are responsible for the ports' and infrastructure development; ports' and terminals' operators, incl. cargo handling companies; international associations and corporations involved in the port-related supply and value chains; shipping companies, ship building yards; relevant academic and research institutions as well as regional industries that might benefit from governmental investments.

3. State of the Art: Digital technologies in ports

Ports serve as the central hub for most trade flows and play an overall crucial role in world-wide trade. To continuously strengthen their ports and to keep up with the overall economic development countries started investing heavily in automation technology within their port industry. Especially in Europe, the ports and the countries are in fierce competition over their port's technological advancement. This is due to the close proximity of the ports and their importance for each country. China, theoretically able to keep up with the European advancement, slows the development down purposely due to too many jobs being tied to the port and the wages are still low enough [9].

Different technologies are seen as crucial parts of the overall development of ports towards a so-called "Smart-Port". The development of ports towards a Smart-Port takes place in five Stages (0 to 5) [10].

The first stage, **Stage 0**, is where ports have no automation at all.

The second stage, **Stage 1**, includes individual automation. Port authorities, ports and other related organizations digitalise their own processes. In this stage, first advantages of the digital advancement such as improved safety and risk management or better infrastructure maintenance can be achieved.

The third stage, **Stage 2**, is where all port-involved companies integrate their systems to achieve better communication. A single digital environment is created and several advantages such as better coordination and reduction of waiting times for all means of transportation can be achieved. An integrated system like this could be one possible application area for a block-chain-based system.

In the fourth stage, **Stage 3**, the port and the hinterland players are connected through one single digital environment, the advantages of the previous stages are extended to even more stakeholders. Additional advantages are expected in overall planning and scheduling within the port and its hinterland.

The last stage, Stage "**Smart-Ports**", connects all stakeholders of the industry with each other, adding on to the previous stages other ports and additional logistics partners and stakeholders are added to the communication network. Scheduling of the various transport modes can be improved and real time cargo tracking with all relevant players involved can be enabled.

To more specifically pin point digital technology developments in the port industry an overview of pilot projects and first activities will be given. Two areas will be looked at. The first area will be European ports in the North and Baltic Sea, particularly larger ones, such as port of Rotterdam and port of Hamburg. The identification of the technological advancements in those large ports will help to better show the possible steps that smaller ports can eventually take. Secondly ports from the South Baltic Sea Region (SBSR) will be considered with a focus on the region and the given conditions of small ports.

3.1 Europe

3.1.1 Rotterdam

Figure 1: Location of Rotterdam

Source. Authors' illustration.

The port of Rotterdam is one of the technological most advanced ports in the world. The port prides itself in being one of the most advanced too, as can be derived by one of the statements made by the CFO of the Port Paul Smits: "*Here in Rotterdam, we are taking action to become the smartest port in the world*" [11].

In the port of Rotterdam, a solid digitalised infrastructure serves as the prerequisite for successful shift towards digitalised processes. Quay walls, dolphins, roads and other structures through Rotterdam's port area have been equipped with sensors. These sensors constantly collect and transmit data.

In April 2018, the port of Rotterdam introduced the first version of a digital platform named **"Pronto"**. With the help of Pronto different actors can be connected within the port. It is expected that through the platform e.g. the time spent by ships can be reduced by up to 20%. The capacities of the port terminal and other services, such as the refuelling of ships and the maintenance can be better synchronised by the platform. With over 30,000 port calls, it is of great importance to make the processes efficient and to make information available quickly to many participants. Water levels, arrival and departure time information can simply be retrieved and shared through Pronto. Current data as well forecasts are provided. Through standardised data formats, reading and evaluating of has been simplified for the participants. The intelligent and efficient planning, which is made possible by the system, benefits the entire port including all stakeholders [12].

Pronto brings shipping companies, agents, terminal operators and other service providers together in a joint platform. This enables the different partners to easily exchange information e.g. concerning their port calls. Pronto can display any activity of each vessel and through the system all the involved partners are able to follow the vessel in real time, knowing exactly when they can expect it to arrive for any services or procedures that they might be involved in. The Pronto system combines the user generated data with the sensor generated data such as weather data. With this combination, Pronto can analyse and forecast information to the participants. Confidential information is not shared by the system. A dashboard like application gives user full control over what information they see and let them time their own activity to increase their own and the overall efficiency within the port [12].

3.1.2 Hamburg

Figure 2: Location of Hamburg

Source. Authors' illustration.

The port of Hamburg is one of the biggest ports in Europe. The Hamburg Port Authority introduced a programme called "**Smart Port**". The control system combines sensor technology and modern communication systems. The *Smart Port* concept is divided into two sections. The first section is the *Smart Port* logistic section where through intelligent solutions the flow of traffic and goods is improved. The sub sectors within this section are traffic flow, infrastructure and flow of goods. Through this programme, several advantages are expected for the port and its customers/ users.

- Navigation in real time
- Shore power from renewable energies
- Intelligent railway points
- Mobile all-purpose sensors
- Smart maintenance
- Virtual depots
- Port monitor
- E-mobility in the port
- Enhanced parking
- Renewable energies

These are the most important aspects of the port development towards a smart port. All the three transportation modes (Road, Track and Sea) will be covered [13]. Other topics that the port of Hamburg is focusing on in the context of digitalisation are underwater drones, autonomously driving truck or paperless customs clearance.

The rail, road and water traffic is already digitally controlled in the port. Monitoring of infrastructure is expected to be done by drones in the future and a current project called "Green4Transport" aims at guiding trucks in columns over intersection to enable better traffic management.

Overall, the port is setting a good pace having already connected 2,000 companies into their systems and their degree of digitisation is about 95%. The Hamburg Vessel Coordination Centre (HVCC) shows how well a digital network can function. Ship-owners, Nautical Centres, competing terminals and even inland waterway companies are connected through one system and benefit from the shared distributed data [14].

3.2 South Baltic Sea Region

3.2.1 Wismar

Figure 3: Location of Wismar

Source. Authors' illustration.

The port of Wismar is a well-connected port in the centre of Mecklenburg Western Pomerania. Its geographic location makes it very suitable for north-south traffic between Scandinavia and Central Europe. The average yearly turnover is about eight million tons. In terms of digitalisation, the Seaport of Wismar has integrated a variety of digital processes:

1. *Access control:* Through the use of RFID technology, the port manages its asset and access control (e.g. access to yard, vehicles and buildings). This makes the movement easier for the employees and also for visitors. Additionally, with this technology usage can be traced – e.g. who used which vehicle at what time.

2. *Intranet-Connect:* The ports intranet assists in interdisciplinary projects and created paperless communication. It also serves an internal wiki and bulletin board.
3. *Electronic Job Orders:* Electronic version of all the job-related details and documents. Additionally, serves as a backup. This system is the basis for B2B partner platforms.
4. *Warehouse (Storage) App.* Information on inventories, stock movements, processing status and documents such as invoices, damage protocol, quality certificates etc. The system application gives users full transparency over all the processes and the data is available 24/7.
5. *Automated main entrance:* Fully automated access management to the port without the need of a gatekeeper.
6. *Planned projects:* Besides the previously implemented technologies, the Seaport of Wismar plans to introduce a variety of new technologies in the future. Examples are IoT applications for maintenance work, 3D-PCs for forklifts, blockchain analysis methods and the use of drones for site surveillance.

3.2.2 Klaipeda

Figure 4: Location of Klaipeda

Source. Authors' illustration.

The port of Klaipeda is an important transport hub for the Baltic countries. The port is the northernmost ice-free port on the eastern coast of the Baltic Sea. It is a multipurpose, universal and deep-water port [15].

3.2.3 Lubmin

Figure 5: Location of Lubmin

Source. Authors' illustration.

The industrial port of Lubmin is located in the district of Western Pomerania –Greifswald, on the southern Greifswalder' bay (German: Greifswalder Bodden) between Greifswald and Wolgast. The harbor facility has a 740-meter-long south quay with five moorings and a 115-meter-long east quay with a mooring. With a water depth of seven meters, the port can be used by ships with a draft of up to 6.10 meters [16].

3.2.4 Vierow

Figure 6: Location of Vierow

Source. Authors' illustration.

The port of Vierow is a small port in east Germany. The port has two quays with lengths of 120 meters and 140 meters. The port is ice-free throughout the whole year and has maximum depth of 6.5 meters [17].

3.2.5 Rostock

Figure 7: Location of Rostock

Source. Authors' illustration.

The port of Rostock is a versatile universal port. The port is connected to rail, road and water. The port has direct access to the Baltic Sea. The total quay length is 2.200 meters and the port is ice-free throughout the whole year [18].

3.2.6 Stralsund

Figure 8: Location of Stralsund

Source. Authors' illustration.

The Port of Stralsund is a port in Mecklenburg-Western Pomerania with a quay length of 2,700 meters. The navigable depth is 6.60 meters. The port has good access to the European inland waterways system [19].

3.2.7 Karlskrona

Figure 9: Location of Karlskrona

Source. Authors' illustration.

The port of Karlskrona is one of the main entry ports for cargo entering between Poland and Sweden. Karlskrona Baltic Port (KBP) is located in the port area, which has a ferry port. There is stevedoring and intermodal terminal operations in the port. There exists good synergies with other companies, such as Stena Line, which has a strong international experience in maritime shipping. Port develops into a complete and environmentally friendly hub for reloading and storing goods. Due to innovative partnerships with other companies, such as rail operators this leads to attractive intermodal solutions for the SBSR. The port is ice-free throughout the whole year.

3.2.8 Karlshamn

Figure 10: Location of Karlshamn

Source. Authors' illustration.

The port of Karlshamn is one of the largest in Sweden as well as the largest and deepest in the southeast of the country. There are six port areas with altogether three kilometers of quay and 750 000 m² of surface area. The sea approach is short and easily navigated. The port is free of ice and unaffected by tides [20].

4. Development of cross-border digital auditing tool for small ports

Performance measurement in ports has a long-standing history. Although there exist a broad range of concepts and approaches in research landscape and practice, there is no universal standard model that is applicable for each study case. Generally, the majority of performance measurement concepts have in common that they focus on so-called KPIs (Key Performance Indicators). In the context of ports, KPIs are often transformed to PPIs (Port Performance Indicators), which demonstrates the target-oriented purpose (e.g. [21], [22], etc.).

A well-known reference and starting point for the research on PPM (Port Performance Measurement) represents the developed concept from UNCTAD (United Nation Conference on Trade and Development) in 1976, which is still widely accepted and used [23]. Following the findings from the conducted literature review, it can be stated that the majority of research efforts within the last decades resulted in the analysis of port performance in the context of container ports or CTLs (container transport logistics), respectively (e.g. [24] – [28]). Accordingly, the research focus mainly on performance measurement of large ports, whereby the examinations on small and medium-sized ports had been neglected, since investigations that take into account the specific characteristics of small and medium-sized ports represents the exception [19], [29] – [32].

Furthermore, since the aim of the present study report is to elaborate an auditing tool for analysing the digital status of small and medium-sized seaports in SBSR or even entire BSR, it needs to be mentioned that this specific target group have not a primary focus on container handling [29], which applies regularly also to other small and medium-sized seaports that are located outside the region. By taking also the larger seaports of BSR into account and comparing the situation with the North Sea, it can be stated that generally container transport plays a subordinate role in BSR [19]. Therefore, it can be further derived that the existing PPI-concepts in the research landscape are not appropriate and adequate as a suitable reference point for the purposes of the present study. Indeed, due to the raising interest in digitalisation issues, novel PPI-concepts – as the one from Ha et al. [28] – integrated additional indicators like "IT system", "Databases", "Networks", "Integrated EDI for communication", "Integrated IT to share data" and "Collaborate with channel members", but generally focus on container ports. Moreover, these PPIs also do not comprehensively cover the wide range of existing novel technologies, which can be among other things traced back to fact that these concepts were not originally developed for the objective to analyse the digital performance of ports. Against this, another research study that needs to be mentioned in this context is the one of Tsamboulas et al. [33], who developed PPIs for measuring the performance of the PCS (Port Community System). However, since the primary focus of this latter research study also do not laid on the performance measurement of digitalisation in ports, it is also less suitable for the aim of this present research. On the other hand, by summarising interim the gathered findings from the conducted literature review, it can be stated that the development of a digital auditing tool for ports – and in particular for small and medium-sized ports – represents a clear research gap that needs to be closed.

Due to the lack of target-group-oriented theories and concepts, another reference point needs to be found for the development of the digital auditing tool for small and medium-sized ports. Through an extensive literature review, a new promising research trend was identified by so-called readiness indexes and maturity models that currently increasingly focus on digitalisation and especially Industry 4.0. As mentioned by Decker and Blaschczok [34], the term digitalisation implies a revolutionary change of the industrial and economic system. Moreover, nowadays, digitalisation means that information and communication technologies are integrated to a high degree in all business processes and activities. Thereby, Industry 4.0 represents the allegory of the digitalisation idea in the industrial – especially manufacturing – sector and thus, is often described as the fourth industrial revolution, which builds upon the introduction of mechanical plants and production lines in the first and second industrial revolutions, and subsequently, the introduction of electronics and information technologies in the course of the third industrial revolution [35]. With other words, Industry 4.0 is regarded as the digital transformation process of the industry, which is enabled and forced by the rapid technology development [36].

Digital and Industry 4.0 readiness indexes are well-known in the context of performance measurements among different nations. Prominent indexes that examine on a macro level the digital performance differences of nations are among other things the NRI (Networked Readiness Index) from the World Economic Forum [37], Industry 4.0 Readiness Index from the consultancy company Roland Berger [38] and the DiGiX (Digitisation Index) from BBVA Research [39]. Not all of these digital readiness indexes on macro level are completely new, but new is the emerging trend in recent years and growing number of digitalisation and Industry 4.0 readiness indexes that put into focus the company perspective and thus are applied on micro level. In addition, these micro indexes are complemented by digital and Industry 4.0 maturity models that investigate the digitalisation level of a company and rank the benchmarked firms into a sequence of order. According to Rajnai and Kocsis [36], digitalisation and Industry 4.0 readiness assessments and maturity models can support the management at benchmarking, and setting up a roadmap for the digital transformation of companies by auditing the current digitalisation status of benchmarked companies.

Most of the digitalisation and Industry 4.0 readiness indexes and maturity models on micro level focus on the assessment of manufacturing companies, which can be traced back to the fact that they represent the main target group in the context of Industry 4.0. Especially the logistics sector is relatively unaffected by digitalisation and Industry 4.0 readiness indexes and maturity models. Accordingly, Decker and Blaschczok [34] claimed to be the first who developed a digital readiness analysis in the logistics sector. In their research focus was the development of a digital readiness index for LSPs (Logistics Service Providers). Our conducted literature review confirmed this, and further revealed that so far, no digital readiness index and maturity model exist for ports. Despite the lack of comparable studies that focus on digital performance indexing of ports, the great amount of evolved readiness assessment models from recent years that concentrate mainly on the manufacturing sector, at least represents a good starting and reference point for the development of the envisaged digital auditing tool for ports. For instance, Basl and Doucek [40] studied 22 digital as well as Industry 4.0 readiness indexes and maturity models. Our literature research discovered additional related indexes and models. Accordingly, based on the identified, analysed and triangulated literature findings from the research landscape and practice about PPIs as well as digital and Industry 4.0 readiness indexes and maturity models as well as practical findings that had been elaborated in the course of the EU-project Connect2SmallPorts, we propose our digital auditing tool for ports in the following Table 1. Since the developed concept at the same time represents a digital readiness index for ports, we call it DRIP.

Table 1: DRIP for measuring the digital performance of ports

Dimension	Weight	No.	Indicator (* = PPI)	Source
Management	20%	1.	Digitalisation Strategy (incl. Governance, Standards, Cultural Guidelines, Progress Indicators, etc.)	[35], [36], [41] – [51]
		2.	Digital Business Model	[34], [45], [47], [50] – [53]
		3.	Investments in Digitalisation	[34], [36], [41], [42], [47], [54]
		4.	Innovation Cooperation	[34], [35], [43], [46], [47], [49]
Human Capital	20%	5.	IT Knowledge & Skills (Education)*	[28], [34], [42] – [45], [47], [49], [50], [55], [56]
		6.	IT Capabilities*	[28], [36], [41], [42], [47], [49], [57], [58]
		7.	IT Training & Education Opportunities*	[28], [35], [42], [45], [47] – [49], [59]
Functionality (IT)	25%	8.	Integrated Communications Infrastructure*	[28], [33], [47], [49] – [51]
		9.	Information regarding Status of Shipment*	[23], [58], [60]
		10.	On-time of Information*	[33], [51], [58], [61]

		11.	Operating System*	[28], [33], [47], [50]
		12.	Processes*	[28], [33], [44], [47], [49] – [51], [59]
		13.	Security	[36], [41], [42], [44], [47], [49], [51], [54], [61]
Technology	30%	14.	Smart ERP System	[28], [34], [51], [54], [55], [59], [61], [62]
		15.	Smart WMS System	[34], [47], [54], [59]
		16.	Smart PCS System (incl. Electronic SCM System)	[47], [48], [54] – [56], [59], [61]
		17.	Web-based Communication Plat-form	[28], [34], [47]
		18.	Mobile Data Access for Employees	[28], [34], [36], [41], [42], [47], [54], [55]
		19.	Mobile Data Access for Custom-ers	[28], [34], [36], [41], [47], [54]
		20.	IoT (incl. Machine-to-Machine-Communication)	[34], [36], [41], [43], [47], [48], [51], [61] – [63]
		21.	Cloud Computing (SaaS, PaaS, IaaS)	[34] – [36], [41], [43], [47], [50], [51], [55], [56], [59], [61] – [63]
		22.	Localisation Technologies (GPS, RFID, etc.)	[34], [36], [41], [43], [47], [52], [55]
		23.	Sensors (Humidity, Temperature, etc.)	[34], [36], [41], [44], [47], [49], [51], [52], [59], [61] – [63]

		24.	Big Data & Predictive Analytics (e.g. for Maintenance, etc.)	[34], [36], [41], [43], [44], [46] – [51], [61] – [63]
		25.	Blockchain (incl. Smart Contracts)	[34], [51]
		26.	Artificial Intelligence (AI)	[34], [49], [51], [63]
		27.	Robotics	[34], [59], [63]
		28.	Drones (Air, Land, Water)	[34], [48]
		29.	Autonomous Solutions (Terminals, Cranes, Vehicles) – CPS (Cyber-Physical Systems)	[34], [47], [49], [51], [63]
		30.	Digital Twinning, Augmented & Virtual Reality (incl. Simulation)	[34], [43], [44], [46] – [51], [59], [61] – [63]
		31.	Personal Network	[34]
		32.	Printed Media	[34]
		33.	Internet	[34]
		34.	Social Media Resources	[34]
Information	5%	35.	Fairs	
		36.	Conferences	
		37.	Associations (e.g. Consultancy, etc.)	[34]
		38.	Scientific Institutions	[34]

Source. Authors' illustration and compilation

As shown in Table 1, our digital auditing tool (DRIP) embraces five dimensions and 38 related indicators, whereby some of them represent PPIs. The five dimensions – namely: management, human capital, functionality (IT), technology and information – were integrated into the tool, since the digital transformation process of companies or ports, respectively, is not ensured by only using novel technologies. It is more the interplay of management measures and employees' knowledge, skills and capabilities as well as functional and prepared IT processes and systems with these digital technologies and solutions; and vice versa, all dimensions with each other, in order to facilitate a sustainable digital transition towards a smart port. Furthermore, it is important that a comprehensive and sustainable information procurement is envisaged in order to be well informed about the current digitalisation trends. Especially this ensures the right identification of appropriate digital measures and investments – i.e. decision making. The indicated weighting factors represent the importance of each dimension, which had been determined during expert interviews with project partners.

All chosen indicators are equally weighted in each dimension and are gathered in form of qualitative data according to a six-item Likert-scale, which at the same time secures the practical application friendliness for a potential digital readiness self-assessment. Accordingly, the developed tool addresses both, practitioners and researchers. For instance, in the course of the first indicators that belong to the dimension management – i.e. digitalisation strategy, digital business model, innovation cooperation – the current implementation status is questioned, whereby in case of the indicator investments in digitalisation the share of digital investments in relation to total investments is analysed according to a pre-defined six-item ordinal scale. In the frame of the dimension human capital, the percentage of employees with special IT education background, the skill level of employees' capabilities and the scope of training and education possibilities is determined in a similar qualitative way. The dimension functionality mainly refers to the implemented and developed overall IT system. Accordingly, the degree of adequacy of the integrated communications infrastructure, accuracy of information regarding status of shipment, provision of on-time of information, compatibility of the operating system, adaptability of the processes for meeting customer requirements and needs, as well as the degree of IT security is measured. Regarding the technology dimension, a comprehensive amount of digital technologies and solutions is listed as indicators, which are regarded as the enablers in research and practice for the digital transformation process. All these indicators are measured by questioning whether the technology is generally known or any use case is known, and if yes, the degree and scope of future or current implementation. Lastly, in the dimension that refers to information, the degree of information procurement is examined according to the indicated information sources that function as indicators. Finally, through this kind of measurement procedure, the digital performance status of ports as well as the digital readiness can be identified and examined.

5. Extension of cross-border digital auditing tool for small ports

Deeply rooted in the fact that in the course of EU-project Connect2SmallPorts, the audited ports will be benchmarked in the further project progress, the presented digital auditing tool from chapter four needs be extended by a component part that enables to measure the operating performance of ports. This is crucial in order to secure a sustainable and smart classification of the audited ports in the course of the aspired and future benchmark activities. For instance, some of the ports are classical cargo-oriented ports, whereas other ports are pure ferry ports, while a third group of ports focus on both – passengers and cargo. Furthermore, from this point of view, the general issue might be raised, whether a ferry or a cargo-oriented port requires more up-to-date digital technologies. With other words, it can be claimed that both kinds or types of ports require different digital technologies for improving their material, financial and information flow. Nevertheless, since the primary focus in the EU-project Connect2SmallPorts lays on cargo handling ports, in the frame of the final evaluation of the received digital auditing results as well as in the course of the future benchmark activities, the different ports that participated in the auditing process needs to be classified in different operating performance groups. Further examples are the geographically conditions, which the different ports face, and also could have a great impact or influence on the demanded digital technologies by ports, et vice versa, the impact or influence of the geographically conditions on the operating performance of the ports (e.g. ship turnaround time). Accordingly, the incorporation of operating performance indicators in the auditing process ensures the profound interpretation of the received results, which had been gathered by the application of the DRIP model from chapter 4.

On the other hand, as highlighted in the previous chapter four and derived from the conducted and presented literature findings, operating performance measurement in ports is a quite common procedure. Additionally, since the primary focus of the EU-project Connect2SmallPorts lays on the research of digital technologies in the port sector, the operating performance measurement part can be minimised and regarded as a general introduction part. Accordingly, based on the identified, analysed and triangulated literature findings from the research landscape and practice about PPIs as well as digital and Industry 4.0 readiness indexes and maturity models as well as practical findings that had been elaborated in the course of the EU-project Connect2SmallPorts, in the following Table 2, the extension of the DRIP model is presented, which ensures the measurement of operating performance aspects of ports and guarantees a sufficient classification of the ports in different operating performance groups.

Table 2: Extension for measuring the operating performance of ports

Dimension	Weight	No.	Indicator (* = PPI)	Source
Productivity	40%	1.	Berth Occupancy*	[28], [33], [64] – [66]
		2.	Storage Utilisation (Yard)*	[28], [64]
		3.	Labour Productivity*	[28], [59], [65], [67], [68]
		4.	Cargo Throughput* (with regard to Passenger Transition)	[28], [33], [59], [64], [69]
Finance	30%	5.	Annual Gross Revenue (from Cargo Operations)*	[33]
		6.	Port Costs by Unit of Cargo handled*	[33], [65]
Lead-Time	30%	7.	Ship Turnaround Time*	[28], [33], [57], [64] – [66], [69]
		8.	Overall Time of Cargo in Port*	[33], [65]

Source. Authors' illustration and compilation

As shown in Table 2, the extension of the DRIP model – i.e. operating performance measurement section – embraces three dimensions and eight related indicators, whereby all of them represent classical PPIs. The three dimensions – productivity, finance, lead-time – and especially the related PPIs were integrated into the tool, since they are relatively unaffected by the circumstance which type of cargo is handled in the port or whether only passengers represent the primary port focus. Moreover, at the same time, this is also the reason why PPIs that mainly targets to measure the container handling performance, had been excluded (cf. chapter four: container traffic plays a subordinate role in the BSR and especially in the case of small and medium-sized ports). Again, the indicated weighting factors represent the importance of each dimension, which had been determined during expert interviews with project partners.

Similar as in the DRIP model from chapter 4, all chosen indicators are equally weighted in each dimension, but this time, are gathered in form of quantitative data. Accordingly, through this kind of extension in form of an operating performance measurement section, the audited ports can be classified in different operating performance groups in the further project progress, which at the same time ensues the right interpretation of the received results from the application of the DRIP model. Furthermore, it becomes possible to examine whether the digital performance of ports has an influence or impact on the operating performance of ports.

In order to sum up, it can be stated that the holistic digital auditing procedures will base on a mixture of qualitative (digital performance measurement – cf. chapter 4) and quantitative approach (operating performance measurement – cf. chapter 5). The summarised interview guide that bases on both, the DRIP (cf. chapter 4) and the operating PPIs (cf. chapter 5), is presented in the appendix of this present study report.

6. Development of cross-border digital auditing tool application procedure

Table 3: Rotation Schedule – Auditing Calendar 2019 & 2020

Jul. 19	Port of Haldensleben (Pilot and Pre-Test)	Rostock Freight and Fishing Port (Pre-Test)
Aug. 19	Port of Lubmin (Pre-Test)	Seaport of Wismar – PP6 (Pre-Test)
Sep. 19	Adjustments to digital auditing tool based on findings from conducted pilot and pre-testing.	
Oct. 19	Rostock Freight and Fishing Port	
Nov. 19	Port of Lubmin	Seaport of Wismar – PP6
Dec. 19	Port of Vierow – AP6	Seaport of Stralsund – AP4
Jan. 20	Port of Karlshamn	Port of Karlskrona – PP9
Feb. 20	Port of Klaipeda – PP8	…

Source. Authors' illustration and compilation

The auditing will take place as shown the rotation schedule (cf. Table 3). The agenda will be set individually with each port as they are different in size and have different availability. For all ports, the auditing questions will be thoroughly discussed as well as additional "in-depth" observation and questioning. After each visit, the answers will be evaluated.

The PPs of a project (Connect2SmallPorts) are seeking a number of small and medium-sized ports in SBSR to participate in their digital auditing programme. Next to the geographical limitation, the main target group embrace ports that:

a) build up the so-called comprehensive TEN-T (= medium-sized ports), or
b) do not belong to TEN-T (= small ports).

A minimum of eight ports will be digitally audited in order to improve their cargo flows, environmental and economic efficiency. This will contribute to the central project objective: improving quality and sustainability of transport services offered by small ports, by innovative and environmentally sustainable transport solutions.

7. Discussion and Conclusion

Performance measuring in the port sector has a long-standing history. Nevertheless, as the findings from the conducted literature review in the present study report highlighted, the numerous existing PPI-concepts mainly focus on operational performance measurement in container ports and thus, large seaports. Accordingly, digital performance measurement in ports and especially in small and medium-sized ports was not researched, which represents a general methodological limitation of the present study report due to the lack of prior research studies on the topic (i.e. digital performance measurement in the port sector) and the target group (i.e. small and medium-sized ports). On the other hand, this bears a clear research gap that needs to be closed. Therefore, the addressed research field of the current study expresses a high novelty value and originality, since the focus is dedicated to the challenging and upcoming digitalisation issues that arise in case of small and medium-sized ports. Due to the problem of missing adequate target-group-oriented and topic-related theories and concepts, a reference point was researched by a broad literature review in order to achieve the indicated main research objective of developing a digital auditing tool for small and medium-sized ports. A promising research trend was identified by the emergence of so-called readiness indexes and maturity models that currently increasingly focus on digitalisation and especially Industry 4.0. Accordingly, based on the identified, analysed and synthesised literature findings from the research landscape and practice about PPIs as well as innovative digital and Industry 4.0 readiness indexes and maturity models as well as practical findings that had been originally collected in the course of the EU-project Connect2SmallPorts, a digital auditing tool for small and medium-sized ports was elaborated and presented. The research findings in form of the developed digital auditing tool for small and medium-sized ports with five dimensions and 38 selected indicators are a first approaching step to tackle the identified research gap.

By defining the indicators, a special focus laid on the distinct features of small and medium sized seaports in the BSR. For instance, small and medium-sized seaports in the region do not focus primary on container handling. Furthermore, the majority of small and medium-sized ports in the BSR currently have no knowledge about the already existing wide range of digital technologies. Therefore, special premise during the development of the digital auditing tool also laid on the application friendliness of the concept in order to found digitalisation awareness raising during potential self-assessment by applying the digital auditing tool. In addition, for this reason, the digital auditing tool also represents a digital readiness index, by what it becomes feasible to investigate the digital readiness of small and medium-sized seaports. The choice to develop the digital auditing tool in form of a digital readiness index was also driven by the circumstance that BSR small ports' knowledge about digital technologies is limited and thus, it cannot be assumed that they already matured in the digital context. Accordingly, they are still in a preparatory stage or with other words: they are still before the real digital transformation process.

Additionally, through the incorporation of a growing number of ports in the frame of future project and research activities and thus, the planned overall auditing process, small and medium-sized ports in the region will be benchmarked according to their digital performance. This will also deliver insights in potential sustainable digital development directions in form of best practices that need to be identified for a resource saving (especially: financial-sparing) appropriate evolution towards a smart port. Moreover, this will assist and contribute to port authorities and operators as well as policy makers and other port-related stakeholders during decision-making, and supports the finding and definition of an efficient and effective strategic direction by setting up a roadmap for the digital transformation in ports. Accordingly, the developed concept addresses both, practitioners and researchers, which at the same time expresses its theoretical and practical implications.

On the other hand, through the potential definition of score groups the audited ports can be classified according to their digital performance in the course of the digital readiness index – which usually is also performed in the frame of maturity models. Furthermore, through the incorporation of PPIs that target to measure the operational performance of small ports as shown in chapter 5 of this present study report, it will be possible to investigate the potential relationship between the digital and operational performance of ports. Accordingly, there is enough room for future discussions and research.

The presented tool will be applied in the further discourse of the INTERREG South Baltic project Connect2SmallPorts in the period of October 2019 to February 2020 – as well as ongoing during project lifetime and beyond. Thereby, firstly, small and medium-sized seaports that are project and associated partners will be assessed through expert interviews. Afterwards, the concept will be applied on project-external small and medium-sized ports. In doing so, the geographical focus is not limited on small ports that are located in the SBSR and thus, it is planned to extend the auditing procedures on the entire BSR. Accordingly, future research findings and thus, first empirical results that are achieved by the application of the presented digital auditing tool are expected at the beginning of the year 2020.

CONNECT2SMALLPORTS Interreg South Baltic EUROPEAN UNION European Regional Development Fund

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Appendix

Interview guide

What is the name of your port?

Name: ______________________

Operational performance measurement

Productivity

1. What is your (expected) cargo throughput in 2019?

Cargo throughput = ___________ tonnes

2. What is your (expected) passenger transition/transit in 2019?

Passenger transition = ___________ passengers

3. What cargo types do you handle and what is the respective proportion (based on the total cargo throughput in 2019)?

	Type of Cargo	Proportion
☐	Liquid bulk goods	________ %
☐	Dry bulk goods	________ %
☐	Containers	________ %
☐	Ro-Ro mobile self-propelled units	________ %
☐	Ro-Ro mobile non self-propelled units	________ %
☐	Others not specified	________ %

4. What is your (expected) berth occupancy in 2019? *(**Optional** for project-external ports, but for PPs and APs mandatory)*

$$\text{Berth occupancy} = \frac{\text{Average no. of days (per year) berth is occupied}}{365} = \_\_\_\_\_\_\_\_ \%$$

Berth occupancy is the ratio of time the berth is occupied by a vessel to the total time available in that period. High berth occupancy is a sign of congestion (>70%) and hence decline of services, while low berth occupancy signifies underutilization of resources (<50%) (UNCTAD, 1976)

5. What is your (expected) storage utilisation (yard) in 2019? *(**Optional** for project-external ports, but for PPs and APs mandatory)*

$$\text{Yard utilisation} = \frac{\text{Average no. of occupied storage slots}}{\text{No. of available slots}} = \_\_\_\_\_\_\_\_\_\_ \%$$

Finance

6. What is your (expected) annual gross revenue in 2019?

Annual gross revenue overall = ___________ EUR

Annual gross revenue from cargo operations = ___________ EUR

7. What are your (expected) port costs by unit of cargo handled in 2019? *(**Optional** for project-external ports, but for PPs and APs mandatory)*

Port costs by unit of cargo handled = ___________ EUR/unit

Lead Time

8. What is your (expected) average ship turnaround time in 2019? *(**Optional** for project-external ports, but for PPs and APs mandatory)*

Average ship turnaround time = ___________ days/call

This is the total time, spent by the vessel in port, during a given call. It is the sum of waiting time, plus berthing time, plus service time (i.e. ship's time at berth), plus sailing delay. Ideally, ship turnaround should be only marginally longer than ship's time at berth and thus waiting time in particular should be as near to zero as possible (Esmer, 2008, p. 250).

9. What is your (expected) average overall time of cargo in port in 2019? *(**Optional** for project-external ports, but for PPs and APs mandatory)*

Average overall time of cargo in port = ___________ h

Digital performance measurement

Management

10. What is the implementation status of your digitalisation strategy (incl. governance, standards, cultural guidelines, progress indicators, etc.)?

No digitalisation strategy exist.	Pilot initiatives are planned.	Digitalisation strategy is in development phase.	Digitalisation strategy is formulated and defined.	Digitalisation strategy is in implementation phase.	Digitalisation strategy is implemented.

11. What is the implementation status of your digital business model(s)?

No digital business model exist.	Pilot initiatives are planned.	Digital business model(s) is/are in development phase.	Digital business model(s) is/are formulated and defined.	Digital business model(s) is/are in implementation phase.	Digital business model(s) is/are implemented.

12. What is the implementation status of your innovation cooperations?

No innovation cooperations exist.	Pilot initiatives are planned.	Innovation co-operations are in development phase.	Innovation co-operations are formulated and defined.	Innovation co-operations are in implementation phase.	Innovation co-operations are implemented.

13. What is your Share of Digital Investments (x) in relation to total investments?

x ≤ 10%	10 < x ≤ 20%	20 < x ≤ 30%	30 < x ≤ 40%	40 < x ≤ 50%	x > 50%

Human Capital

14. What is the proportion of employees with special IT education background (x)?

x ≤ 10%	10 < x ≤ 20%	20 < x ≤ 30%	30 < x ≤ 40%	40 < x ≤ 50%	x > 50%

15. What is the skill level (capabilities) of your employees regarding the following topics?

	Very bad	Bad	Rather bad	Rather good	Good	Very good
IT infrastructure						
Automation technology						
Data analytics						
Data security / communications security						
Development of / application of assistance systems						
Collaboration software						
Non-technical skills such as systems thinking and process understanding						

16. How would you evaluate the scope of training and education possibilities for your employees?

Very bad	Bad	Rather bad	Rather good	Good	Very good

Functionality (IT)

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17. How do you evaluate the adequacy of your integrated communications infrastructure?

Very bad	Bad	Rather bad	Rather good	Good	Very good

18. How do you evaluate the accuracy of information regarding status of shipment?

Very bad	Bad	Rather bad	Rather good	Good	Very good

19. How do you evaluate the provision of on-time of information?

Very bad	Bad	Rather bad	Rather good	Good	Very good

20. How do you evaluate the compatibility of your operating system?

Very bad	Bad	Rather bad	Rather good	Good	Very good

21. How do you evaluate the degree of process adaptability in meeting customer requirements?

Very bad	Bad	Rather bad	Rather good	Good	Very good

22. How do you evaluate the degree of IT security?

Very bad	Bad	Rather bad	Rather good	Good	Very good

Technology

23. How do you evaluate the degree of usage regarding the following technologies and systems?

	Technology not known	No use case available	Usage not planned	Usage is planned	In specific projects already implemented	Comprehensive usage
Smart Enterprise-Resource-Planning-System						
Smart Warehouse-Management-System						
Smart Port-Community-System (incl. Electronic Supply-Chain-Management-System)						
Web-based Communication Platforms						
Mobile Data Access for Employees						
Mobile Data Access for Customers						
Internet-of-Tings (incl. Machine-to-Machine-Communication)						

Cloud Computing (Software-as-a-Service – SaaS, Platform-as-a-Service – PaaS, Infrastructure-as-a-Service – IaaS)						
Localisation Technologies (GPS, RFID, etc.)						
Sensors (Humidity, Temperature, etc.)						
Big Data and Predictive Analytics (incl. Maintenance, etc.)						
Blockchain (incl. Smart Contract Applications)						
Artificial Intelligence (AI)						
Robotics						
Drones (Air, Land, Water)						
Autonomous Solutions (Terminals, Cranes, Vehicles) – Cyber-Physical-Systems (CPS)						
Digital Twinning, Augmented and Virtual Reality (incl. Simulation)						

Information

24. How do you evaluate your degree of information procurement from the following sources regarding the digitalisation theme?

	Very low	Low	Rather low	Rather high	High	Very high

Personal Network						
Printed Media						
Internet						
Social Media						
Fairs						
Conferences						
Associations and Consultancies						
Scientific Institutions						