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Smart Seaports as Innovation Drivers for Blue Growth

Robert Philipp

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Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been previously submitted for a doctoral or equivalent academic degree.

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Nutikad meresadamad kui sinist majanduskasvu vedav innovatsioon

ROBERT PHILIPP

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Contents

List of Publications

The thesis builds upon on the following publications:

I Philipp, R., Prause, G., & Meyer, C. (2020). Blue Growth Potential in South Baltic Sea Region. *Transport and Telecommunication Journal*, 21(1), 69–83. https://doi.org/10.2478/ttj-2020-0006 **(ETIS Classification 1.1)**

II Philipp, R., Gerlitz, L., & Moldabekova, A. (2020). Small and Medium-Sized Seaports on the Digital Track: Tracing Digitalisation across the South Baltic Region by Innovative Auditing Procedures. In: Kabashkin I., Yatskiv I., Prentkovskis O. (eds.) *Reliability and Statistics in Transportation and Communication. RelStat 2019. Lecture Notes in Networks and Systems*, vol 117, pp. 351–362. Springer, Cham. https://doi.org/10.1007/978-3-030-44610-9_35 **(ETIS Classification 3.1)**

III Philipp, R. (2020). Digital Readiness Index Assessment towards Smart Port Development. *Sustainability Management Forum,* 28(1), 49–60. https://doi.org/10.1007/s00550-020-00501-5 **(ETIS Classification 1.2)**

IV Philipp, R., Prause, G., & Gerlitz, L. (2019). Blockchain and Smart Contracts for Entrepreneurial Collaboration in Maritime Supply Chains. *Transport and Telecommunication Journal*, 20(4), 365–378. https://doi.org/10.2478/ttj-2019-0030 **(ETIS Classification 1.1)**

V Philipp, R. (2020). Blockchain for LBG Maritime Energy Contracting and Value Chain Management: A Green Shipping Business Model for Seaports. *Environmental and Climate Technologies*, 24(3), 329–349. https://doi.org/10.2478/rtuect-2020-0107 **(ETIS Classification 1.1)**

Author’s Contribution to the Publications

I Blue Growth Potential in South Baltic Sea Region

The article is a co-authored paper that targeted the forecast of Blue Growth in the South Baltic Sea Region. The author developed, implemented and conducted the online survey, organised the pre-test and was responsible for data collection in Denmark, Germany and Sweden. Two project partners assisted the data collection process in Lithuania and Poland. To achieve an adequate response rate in some target countries, companies were contacted also via telephone and oral surveys. The author performed the data analysis and interpretation as well as the presentation of the results.

II Small and Medium-Sized Seaports on the Digital Track: Tracing Digitalisation across the South Baltic Region by Innovative Auditing Procedures

The article is a co-authored paper that aimed to develop a digital auditing tool. The study builds upon on a comprehensive literature review and expert interviews, both of which were conducted by the author. Based on these data collection activities and analyses, the author developed and presented the digital readiness index for ports (DRIP).

III Digital Readiness Index Assessment towards Smart Port Development

The article is a single-author work and study based on the applied DRIP via an online survey. In the article, the case study results of five selected ports are presented within a benchmark. Furthermore, expert interviews complemented the data gathering process. All data collection activities enabled the development and presentation of the strategic graduation model towards smart port development.

IV Blockchain and Smart Contracts for Entrepreneurial Collaboration in Maritime Supply Chains

The article is a co-authored paper that investigated the application and integration opportunities of Blockchain and Smart Contracts in ports and their environment. The author conducted expert interviews and organised workshops and focus group meetings in the frame of the data gathering process. Field research and observations by the author complemented the data collection. The author performed the data analysis and identified the common functionalities of sustainable Blockchain and Smart Contract usage by developing and presenting two case studies in the context of (1) the charter-party contracting process, and (2) the cargo import in relation to the seaport of Wismar in Germany.

V Blockchain for LBG Maritime Energy Contracting and Value Chain Management: A Green Shipping Business Model for Seaports

The article is a single-author work, which aimed to develop an innovative business model for regional seaports, with a focus on liquefied biogas (LBG). Furthermore, the paper showed that Blockchain and Smart Contracts foster the implementation of the business model and optimisation of value chain operations. Besides the expert interviews, a comparative analysis with ultra-low sulphur fuel oil (ULSFO) was carried out within a case study in the seaport of Karlskrona in Sweden and the RoPax ferries from Stena Line.

Introduction

Ports add value to their surrounding regions, since they provide significant economic and social benefits (Rodrigue & Schulman, 2013). Indeed, ports are the backbone of the transport network, without which the worldwide economy could not exist in its present form (Funke & Yu, 2011). If all economic activities that depend on the sea are cumulated, in 2018, the so-called "Blue Economy" of the European Union (EU) directly employed close to five million people and generated around EUR 750 billion in turnover and EUR 218 billion of gross value added (GVA) (EC, 2020). Seaports represent the main hubs for commercial activities: In the same year, 70% of all goods were transported to or from ports outside the EU-27, making Maritime Transport the most important mode for long distances, while cargo transport between ports in the EU-27 made up 27% (Eurostat, 2020a). In total, 4.1 billion tonnes of freight and 437 million passengers passed through the 1,200 European ports in 2018 (Eurostat, 2020b, 2020c). Furthermore, approximately three million people are employed directly or indirectly in ports across the EU states (EC, 2013a).

However, in the age of globalisation, the focus of policy makers and scientists has been primarily on large ports (Feng & Notteboom, 2013). Hence, small and medium-sized ports are often underestimated and neglected, which is discernible by the lack of research studies on regional ports, different small port closures (Friedrichskoog in Germany, Stigsnæsværkets in Denmark, etc.) and the Trans-European Transport Network (TEN-T) regulations. Regarding the latter, the European Commission (EC), within the issued guidelines for the development of the TEN-T, identified 329 key ports along the European coastline that are slated to become part of a unified network for boosting growth and competiveness in Europe's Single Market (EC, 2013b). The TEN-T will be double-layered; it will consist of a core network (due date 2030) and a comprehensive network (due date 2050). Inside the core network, nine corridors are planned, which will be multi-modal and intended to improve cross-border links (road, rail, waterways) within the EU (ibid.). In this context, European ports are differentiated between (1) core ports, (2) comprehensive ports and (3) non-TEN-T ports. Large ports are in the category of core ports, while medium-sized ports are classified as comprehensive ports. However, small ports are not directly considered within the development plans of the TEN-T, which equals around 871 non-TEN-T ports (73%). To reach this ambitious objective – developing an integrated Trans-European Transport Network (TEN-T) – the EC has launched the financial instrument Connecting Europe Facility (CEF) for the expansion of transport infrastructure, whereby, particularly in the case of the selected key ports, the infrastructure requirements, in conjunction with the development of the hinterland, shall be fulfilled (EC, 2013c). Certainly, it makes economic sense to promote these larger ports in order to reach the envisaged goal – development of a Common European Single Market. However, whether smaller ports can benefit from this development – even if only indirectly – remains doubtful. Indeed, medium-sized ports as comprehensive ports receive financial support via the CEF. Nevertheless, they face a competitive disadvantage with regard to the stronger subsidised core ports, whereas in the case of small ports, which are not considered within the TEN-T plans, the situation is even more challenging. Paradoxically, small ports are also the collectors and repositories of knowledge and ideas and thus constitute the hubs of regional economies that are important gateways for regional development (Allaert, 2006). This is also stressed in the context of green transport corridors, in which smaller ports are regarded as important logistics hubs and germs of logistics clusters that contribute substantially to regional development (Prause, 2014a). Hence, research studies on green transport corridors emphasise the need for the sustainable integration of smaller ports in the TEN-T and their significance for green supply chains as well as entrepreneurship (Hunke, 2015; Hunke & Prause, 2013; Prause, 2014b; Prause & Hunke, 2014). However, considering the favourable conditions of larger ports, it will become increasingly difficult for medium-sized and particularly small ports to keep up with the rapid development of the core ports. Consequently, the performance gap between large ports, on the one hand, and small and medium-sized ports, on the other hand, threatens to become even greater. Thus, competition among the ports will be even more distorted, which, in turn, will contribute to one-sided development. Hence, it will be more difficult for small and medium-sized ports to engage in better supply chain development and integration. In this context, Barros (2005) underlines that the European idea of a Common Single Market increases competition among the European ports, thus obliging the least performing ports to improve their efficiency, but it also can overstrain smaller ports.

Additionally, the situation of smaller ports in the North and Baltic Sea Regions (NSR and BSR) is even more challenging due to the issued directives from the International Maritime Organisation (IMO). To ensure a sustainable reduction of emissions from shipping, the IMO is following a long-term global clean shipping strategy (Olaniyi et al., 2017). Currently, in particular, the sulphur emission regulations pose challenges for the shipping industry – namely, the established Sulphur Emission Control Areas (SECAs) that are enacted in the IMO MARPOL Annex 2, and the introduced global sulphur cap (IMO, 2014, 2016). SECAs exist in the BSR, NSR and English Channel as well as along the American and Canadian coastlines, whereby similar SECA directives are the Chinese regulations for coastal waters (Notteboom, 2011; Olaniyi et al., 2018a). According to the latest gradual adjustment from 1 January 2015, in SECAs, fuel for ships is not allowed to have a sulphur concentration (% w/w) above 0.1% (IMO, 2014). Besides this, since 1 January 2020, the renewed global sulphur cap entered into force, which stipulates the use of fuel for shipping at no more than a 0.5% sulphur concentration (% w/w), i.e. worldwide, outside of SECAs (IMO, 2016). Thus, the ease or exclusive use of heavy fuel oil (HFO) is no longer compliant according to these emission regulations. Taking into account the current technological state of the art, ship-owners have three options to comply with these sulphur restrictions: (1) the installation of emission abatement technologies (e.g. scrubbers), (2) the switch to expensive low sulphur fuels (inside SECAs: low sulphur marine gas oil – LSMGO or ultra-low sulphur fuel oil – ULSFO; outside SECAs: very low sulphur fuel oil – VLSFO), or (3) retrofitting for the usage of alternative fuels (e.g. liquefied natural gas – LNG) (Atari & Prause, 2017). Related to this are the high investment costs for new infrastructure developments and auxiliary emission compliance services, which puts smaller ports especially under pressure (Olaniyi et al., 2018b). This is deeply rooted in the fact that, in the case of core and comprehensive ports, investments in bunker options – in particular for alternative fuels – are supported via the CEF, whereby for core ports, the development of LNG refuelling facilities is even binding (EC, 2013d).

Along with the additional investment requirements, further challenges exist due to the increasing digitalisation in the maritime industry, which must be also managed by small ports in order to remain competitive. The growing significance of digitalisation and related novel technologies has become apparent most recently by the COVID-19 pandemic. In relation to this, digital technologies play an active and crucial role in the provision of needed logistics and transport services. For instance, geographic information systems (GIS) and Big Data analytics are used to balance the supply and demand of limited material resources, e.g. medical supplies (Zhou et al., 2020). Besides this, digital supply chain twins were used to support decision-making during the first pandemic outbreaks (Ivanov, 2020). However, small and medium-sized ports in the BSR have the common problem of unfamiliarity with concepts such as Industry 4.0, the Internet-of-Things (IoT), Blockchain, etc. and how these novel trends and technologies support better environmental and sustainable performance (Philipp et al., 2018). Despite this lack of technological know-how on the part of smaller ports, however, this growing digitalisation not only poses risks for them but also can be seen as a development opportunity. For instance, digitisation in the maritime logistics sector opens the potential for the creation of new business models. For example, scientific studies have shown that, in the frame of Industry 4.0, SMEs can especially benefit (e.g. Prause & Atari, 2017), which should also apply to small and medium-sized ports. Thereby, in the context of ports and digitalisation, the term "smart ports" has received growing attention in recent years. One of the first attempts to define the idea of smart ports can be traced back to Yang et al. (2018), who described visionary a smart port as a fully automated port in which all devices are connected via the IoT, and a network of smart sensors, actuators, wireless devices and data centres form the key infrastructure. As set out by Douaioui et al. (2018), the development towards a smart port is an innovative venture that targets to enhance port competitiveness and foster entrepreneurial collaboration with port stakeholders in order to achieve horizontal and vertical integration of supply chains. Thus, according to Gardeitchik et al. (2017), the digital transformation process in ports is targeted to reach the highest digitalisation level, which is characterised by the smart port vision, whereby ports are optimally connected with their environment and all ports globally with each other through the application of diverse digital technologies. Accordingly, without the inclusion of small and medium-sized ports in this digital development process, the innovative idea of smart ports will remain only a vision. Since smart ports currently do not exist and instead represent an innovative brainchild of the future, the roadmap for the sustainable development and the attainability of this final digital transformative stage is still unclear and has not yet been researched.

By summarising the identified contemporary main drivers, it can be deduced that the framework conditions in the NSR and BSR for small and medium-sized ports, as well as the Maritime Economy in general, are mainly characterised by the TEN-T regulations, the introduced sulphur directives and the progressive digitalisation process. In considering the described problems, it can be stated that the major challenges of small and medium-sized ports are related to the identification of sustainable development opportunities in the context of the digital transformation, as well as new pathways in the form of innovative business models, smarter integration into supply chains and physical and digital infrastructure developments, as well as cost and emission reductions. In relation to this, it has to be noted that there is a general lack of empirical research studies on small and medium-sized ports. Consequently, specific – and often regionally bound – characteristics and perspectives of smaller ports have been studied less thoroughly. For this reason, researchers, such as Feng and Notteboom (2013, 2011), have called for generalised application studies on small and medium-sized ports. In addition, also other scientists ask to tackle the gaps of missing models and concepts in the case of small and medium-sized ports (e.g. Castillo-Manzano et al., 2013; Margarino, 2014;

Olesen et al., 2014a, 2014b). Accordingly, it can be stated that the research on small and medium-sized ports is at the beginning stage.

Nevertheless, filling these research gaps in terms of missing models and concepts, as well as the underestimated role of small and medium-sized ports, will contribute to the EU Blue Growth Strategy, which targets to support sustainable growth in the marine and maritime sector (EC, 2012). The EC has emphasised in the framework of the Blue Growth Strategy that seas and oceans are drivers for the European economy, with a great potential for innovation and growth. Thus, the Blue Growth Strategy contributes to the EU's Integrated Maritime Policy (EC, 2011, 2007) to achieve the goals of the Europe 2020 Strategy for smart, sustainable and integrative growth (EC, 2010).

Based on these insights, the central aim of this doctoral thesis is:

> *To develop a conceptual and processual model that ensures a sustainable digital transformation, so that small and medium-sized ports in the South Baltic Sea Region are enabled to become the main innovation drivers for smart regional growth in terms of the EU Blue Growth Strategy.*

Accordingly, the thesis focuses on the South Baltic Sea Region (SBSR) and its adjoining EU countries, namely, Denmark, Germany, Lithuania, Poland and Sweden. This region was chosen as it is of particular interest concerning maritime transportation. In the first place, the BSR itself is a flagship maritime region in Europe in terms of economic, social and environmental performance (Gerlitz et al., 2018), whereby the transport sector especially is one of its most important economic engines (Beifert et al., 2015). However, in particular, the SBSR has outstanding importance due to the geographically-situated East-West transport corridor (EWTC)[1], which causes that the southern part of the BSR shows up the greatest traffic density (Kusch et al., 2011; Lumiste & Prause, 2011), which is also reinforced by the fact that all BSR-ingoing and -outgoing vessels have to pass the Skagerrak/Kattegat. Considering these sound characteristics, it can be assumed that research outputs that have been developed and proven in the SBSR are generalisable to a certain degree and thus are applicable to other maritime regions and ports.

With regard to the overall objective of the doctoral thesis, it is necessary to examine strategy positions and business models that relate to digitalisation, as well as to develop harmonised and sustainable transport solutions, so that small and medium-sized ports in the SBSR become future flagship gateways with access to the integrated sustainable transport system and thus contribute substantially to smart regional growth. Hence, the thesis seeks to support small and medium-sized ports in the new fast-growing trend of industrial and softer informational digitalisation, thereby allowing them to improve their cargo volumes and transport services by adopting tailor-made powerful novelties coming from the industry (Industry 4.0). Thus, the results of the doctoral thesis will improve the technical, ICT and strategic management capacity of small and medium-sized ports.

[1] The EWTC is a geographically defined infrastructure linkage and intermodal transportation route between Asian countries (China, Kazakhstan, etc.), Russia, Belarus, Ukraine, Black Sea Region countries, SBSR countries (Denmark, Northern Germany, Kaliningrad province, Lithuania, Northern Poland, Southern Sweden) and the markets of Central, Western and Northern Europe (Kusch et al., 2011). The corridor includes several ports, road and railway links and parts of the Nordic Triangle and Corridor IX B/D in Lithuania and Kaliningrad province, whereby the EWTC itself is part of the Northern Transport Axis (Lumiste & Prause, 2011).

This, in turn, will enable the compatibility of port and transport infrastructure in order to achieve better operational and environmental performance.

In this context, one of the most promising technologies with far-reaching potential for supply chain management (SCM) is Blockchain (incl. Smart Contracts) (Kouhizadeh & Sarkis, 2018). As the research results of the doctoral thesis will show, there is a concrete demand by small and medium-sized ports for this technology. Blockchains are often described as open and decentralised ledger systems that allow participants to process transactions and information with each other and without third parties (Chuen, 2015; Gallay et al., 2017; Liao & Wang, 2018; Manski, 2016; Swan, 2015). Smart Contracts that are run on the top of Blockchains are transactional protocols that encompass the conditions of contracts and automatically conduct these negotiated terms (Liao & Wang, 2018). The interest in Blockchain is justified insofar as scientific studies have shown that this technology greatly improves data security and efficiency. Along with this, within Customer Order Management (COM), which commonly forms an integral part of SCM, a reduction of 65% in the processing time for placing orders, 60% in amending orders and around 50% in human-processing savings are achievable (Martinez et al., 2019). Moreover, a study on transport companies by Nelson et al. (2017) showed that the use of Blockchain and Smart Contracts has the potential to increase the profit margin in supply chains by 2% to 4%. Hence, because of the concrete demand for this technology by small and medium-sized ports, as well as the barely developed and implemented cases of its use in the maritime and especially port sector, a special focus in the doctoral thesis is on Blockchain.

Thus, to achieve the overall objective, the following central research questions in the frame of the doctoral thesis will be answered:

RQ1: What is the predicted future Blue Growth potential of the Maritime Economy in the SBSR and what are the impacts from the Digitalisation, TEN-T regulations and IMO Sulphur directives on the sustainable performance of the blue sector? (Article I)

RQ2: How is it possible to assess the digital performance and strategically safeguard the digital transformation in ports? (Articles II & III)

RQ3: How do Blockchain and Smart Contracts improve efficiency in ports and their ecosystems? (Articles IV & V)

In the scientific discourse of the doctoral thesis, the research strategy of methodological triangulation was applied, in which research is designed by the combination of several quantitative and qualitative research methods in order to overcome the weaknesses or intrinsic biases in the case of single-method approaches. Hence, the research builds upon empirical data from surveys, expert interviews, case studies, workshops, focus group meetings, field research and observations that were collected and produced in the frame of four projects that were co-funded by the ERDF (European Regional Development Fund). The quantitative and qualitative data collection activities took place between March 2017 and January 2020.

In the frame of Article I, for the very first time, the future Blue Growth potential was investigated and quantified through a conducted forecast analysis. The study determined that, overall, the future Blue Growth potential in the SBSR can be evaluated as only moderate. Regarding the Maritime Transport sector, it was noticed that the domestic markets have low or, in some cases, moderate growth potential, whereas the predicted future growth potential in the context of international markets is not at all persuasive. Thus, the results revealed that it is important to promote the Maritime Transport sector in order to foster Blue Growth in the SBSR. Furthermore, digitalisation was identified as the most important impact factor for Blue Growth, which underlines the great importance of a strong focus on this contemporary main driver in the actions that need to be taken to facilitate sustainable growth in the region.

The results from Article II set up on a literature review about Port Performance Indicators (PPIs), as well as digital and Industry 4.0 readiness indexes and maturity models for the development of the innovative Digital Readiness Index for Ports (DRIP), which is the first of its kind and facilitates digital performance measurement and digital readiness assessment in ports. Through the application of the DRIP in Article III, the model was subsequently validated. On the basis of the DRIP, the strategic graduation model towards smart port development was elaborated on and also validated in the further research discourse. Thus, through the development of the DRIP towards a digital maturity model (Article III), it became possible to (1) classify ports according to their digital performance and to identify the individual strategic digital positioning of ports, as well as building upon this to (2) derive the respective strategic direction for the sustainable development towards smart ports. Hence, the DRIP model, as well as the strategic graduation model towards smart ports, jointly reveal high relevance and importance, as they safeguard the sustainable digital transformation of ports. Moreover, in the frame of the conducted benchmarking (Article III), the strength and weaknesses of the investigated ports regarding their digital transformation became apparent. Accordingly, it was noticeable that all investigated seaports show low digital readiness, among other things, regarding Blockchain (incl. Smart Contracts), which urges further research studies on the topic, with a particular focus on potential use cases, since Blockchain and Smart Contracts have hardly been implemented and used in ports (Article III).

Correspondingly, the results in Articles IV and V refer to three case studies concerning the implementation of Blockchain and Smart Contracts, which, so far, have not been researched in the scientific literature. The first case (Article IV) investigated the charter-party contracting process (i.e. macro-logistics level) that can be optimised by a Blockchain Smart Contracting system, which, on a first glance, is mainly beneficial for ship-owners, since shipbrokers become superfluous. Nevertheless, this elimination of intermediary levels indirectly also adds value to all the process participants (incl. ports) through the emergence of spill-over effects. The second case (Article IV) focused on the cargo import in a medium-sized port (i.e. micro-logistics level) and highlighted how the internal processes can be improved and the transaction costs decreased through Blockchain and Smart Contract implementation. Both cases are of particular scientific and practical importance, as they jointly show how Blockchain and Smart Contracts foster entrepreneurial collaboration in maritime supply chains, and, at the same time, how small and medium-sized ports become better enabled to integrate themselves into smart supply chains (Article IV). The third case (Article V) examined an innovative business model for regional ports, with a special focus on liquefied biogas (LBG). The results of Article V underline the far-reaching significance of Blockchain technology, as it facilitates the implementation of the elaborated LBG Maritime Energy Contract (MEC) business model as well as optimises the underlying value chain operations.

In reflection of these findings, it was concluded that through an ensured sustainable digital transformation and a special focus on specific enabling technologies, such as Blockchain, small and medium-sized ports can be empowered to become the main innovation drivers for Blue Growth.

The doctoral thesis is structured as follows: In the first chapter, the key concepts are presented as well as the theoretical setting of the dissertation. In the second section, the methodology is described. Building upon this, the research results are briefly showcased (chapter three). In the subsequent chapter four, the main research findings are discussed and the implied implications for the SBSR, small and medium-sized ports, maritime stakeholders and policy makers are derived. The doctoral thesis ends with a conclusion, in which the author's contributions to science and practice are expounded on, and the research limitations and proposals for future research studies are highlighted.

Abbreviations

AI	Artificial Intelligence
BSR	Baltic Sea Region
CAGR	Compound Annual Growth Rate
CEF	Connecting Europe Facility
COM	Customer Order Management
Connect2SmallPorts	South Baltic Small Ports as Gateways towards Integrated Sustainable European Transport System and Blue Growth by Smart Connectivity Solutions (INTERREG Project)
CPS	Cyber-Physical Systems
CSHIPP	Clean Shipping Project Platform (INTERREG Project)
CTL	Container Transport Logistics
DE	Germany
DK	Denmark
DPoS	Delegated-Proof-of-Stake (Consensus Algorithm)
DRIP	Digital Readiness Index for Ports
DWF	Distant-Water Fleet
EC	European Commission
ERDF	European Regional Development Fund
ERP	Enterprise-Resource-Planning
ESC	Energy Service Contract
EU	European Union
EWTC	East-West Transport Corridor
GDP	Gross Domestic Product
GIS	Geographic Information System
GoLNG	LNG Value Chain for Clean Shipping, Green Ports and Blue Growth in Baltic Sea Region (INTERREG Project)
GPS	Global Positioning System
GVA	Gross Value Added
HFO	Heavy Fuel Oil
IaaS	Infrastructure as a Service
ICT	Information and Communications Technology
Industry 4.0	Fourth Industrial Revolution
INTERMARE South Baltic	Internationalization of South Baltic Maritime Economy (INTERREG Project)
IT	Information Technology
IMO	International Maritime Organisation
IoT	Internet-of-Things
KPI	Key Performance Indicator
LBG	Liquefied Biogas
LNG	Liquefied Natural Gas

LSF	Large-Scale Fleet
LSMGO	Low Sulphur Marine Gas Oil
LT	Lithuania
M	Million
MEC	Maritime Energy Contract
MT	Metric Tonnes
Mtoe	Million Tonnes of Oil Equivalent
n.e.c.	Not Elsewhere Classified
No.	Number
NUTS	Nomenclature of Territorial Units for Statistics (French: Nomenclature des Unités Territoriales Statistiques)
NSR	North Sea Region
OECD	Organization for Economic Co-operation and Development
PaaS	Platform as a Service
PBFT	Practical-Byzantine-Fault-Tolerance (Consensus Algorithm)
PCS	Port Community System
PL	Poland
PoET	Proof-of-Elapsed-Time (Consensus Algorithm)
PoS	Proof-of-Stake (Consensus Algorithm)
PoW	Proof-of-Work (Consensus Algorithm)
PPs	Project Partners
PPI	Port Performance Indicator
PPM	Port Performance Measurement
R&D	Research & Development
RFID	Radio-Frequency Identification
RoPax	Roll On/Roll Off a Passenger
RQ	Research Question
S^3	Smart Specialization
SaaS	Software as a Service
SBSR	South Baltic Sea Region
SCM	Supply Chain Management
SE	Sweden
SECA	Sulphur Emission Control Areas
SSCF	Small-Scale Coastal Fleet
TEN-T	Trans-European Transport Network
TEST-4-SME	Laboratory Network for Testing, Characterisation and Conformity Assessment of Electronic Products developed by SMEs (INTERREG Project)
TEU	Twenty-foot Equivalent Unit
UK	United Kingdom
ULSFO	Ultra-Low Sulphur Fuel Oil

UNCTAD	United Nations Conference on Trade and Development
VLSFO	Very Low Sulphur Fuel Oil
VRIN	Valuable, Rare, Imperfectly Imitable and Non-substitutable
WMS	Warehouse Management System

1 Theoretical Framework

The following chapter provides the theoretical and conceptual background of the thesis. It begins with a fundamental analysis of the Maritime Economy in the light of the EU Blue Growth Strategy and an exposition of the current state of the research concerning the main target group, which reveals some common peculiarities and problems of small and medium-sized ports. Building upon this, the digitalisation and related novel technologies in the context of ports is mooted in general, as well as the Blockchain and Smart Contract technology in particular. In addition, the theoretical setting of the dissertation is framed through the disclosure of selected scientific theories.

1.1 The EU Blue Growth Strategy and the New Maritime Economy

The Maritime Economy under the relabelled new term "Blue Economy", became prominent in the European policy context by the EUs agenda Blue Growth Strategy in 2012 (cf. also EC, 2012, 2017a, 2018a). This initiative was kick-started to harness the untapped potential of Europe's oceans, seas and coasts for economic growth and job creation. As such, the EU Blue Growth Strategy represents the maritime dimension of the Europe 2020 Strategy and, as such, is intended to contribute to the EU's international competiveness and resource efficiency (EC, 2012). Hence, the Maritime Economy has been identified as a crucial driver for Europe's welfare and prosperity. The EC made it clear that the inherent long-term potential can only be completely realised if more effective and coordinated steps are taken to integrate the environmental, economic and social aspects of ocean management (EC, 2018a, 2019a, 2020). Since then, the EC has intensified the launching of initiatives in many policy areas related to Europe's oceans, seas and coasts to facilitate the cooperation between maritime businesses and public authorities across borders, sectors and stakeholders, while ensuring the sustainability of the marine environment (EC, 2017a).

In 2017, the Commission released another report on the Blue Growth Strategy and stated that Blue Growth in the EU is still in its early stages. Furthermore, the scope of the previously defined Blue Economy sectors – Living Resources, Non-living Resources (primarily: Oil & Gas), Transport (alias: Shipping), Shipbuilding, Tourism – was extended by the new sector Offshore Renewable Energy, since the subsector Offshore Wind Energy was especially rapidly growing. However, the focus was still on pushing sustainable growth in the Maritime Economy via the following five focus areas (ibid.):

- Aquaculture
- Blue Energy (Offshore Wind Energy and Ocean Energy)
- Maritime, Coastal and Cruise Tourism (alias: Coastal and Maritime Tourism)
- Marine Mineral Resources (alias: Seabed Mining/Seabed Mineral Resources)
- Blue Biotechnology

The EC stressed that this list should not be considered as static, since ongoing and future EU initiatives will be aimed at encouraging innovation in further sectors, which will lead to new areas that emerge over time becoming suitable for further policy focus (EC, 2012). Nevertheless, these five focus areas were selected because of their inherent potential for innovation, technological progress and job creation (EC, 2017a). Worth mentioning is that the EC has always emphasised in the communications of the Blue Growth Strategy the great significance of ports' infrastructure, skills as well as innovation and cluster-forming potential for the development of Blue Growth in the defined sectors and focus areas (EC, 2012, 2017a). Hence, ports play a decisive role within the EU Blue

Growth agenda. Indeed, ports are the main drivers of Blue Growth, since all economic actions concerning the different Blue Economy sectors more or less start at, relate to, or take place via ports; whereby emanating spill-over effects naturally go beyond the Maritime Economy, as ports are key service providers to the entire economy. This is additionally stressed in the EC's communication "Ports: an engine for growth"; here: job creation and economic growth potential in the coastal areas and across the EU as a whole (EC, 2013a).

Since 2018, the EC has published the annual "EU Blue Economy Report" as another step forward in the Blue Growth Strategy, by measuring and monitoring the progress and developments in the Maritime Economy with regard to the underlying sectors. As stated by the EC, one of the main challenges in monitoring the Blue Economy can be seen in the discrepancies between EU member states' relevant national accounts and the economic sectors considered as "blue". Based on these data constraints, the EC revised its definition of the Blue Economy and started to differentiate clearly between the so-called established and emerging sectors in the course of analysing Blue Growth development, which mainly builds upon the primary metric indicators of employment, turnover and GVA. Thereby, the established sectors comprise industry branches with a long-term proven contribution to the Blue Economy. However, maritime or coastal activities are summarised under the emerging sectors if they are in an early stage (R&D) and show high potential for future development, or not enough consistent and comparable data is available for a detailed socioeconomic analysis. Accordingly, some sectors, such as Desalination and Maritime Defence, are by no means new, but due to the lack of suitable data, they are declared as emerging sectors by the EC (EC, 2018a, 2019a, 2020).

Hence, the term Blue Economy is subject to an evolutionary process, since in the progress reports from 2018 to 2020, the scope of activities and (sub)sectors that are ranked as "blue" was expanded. For instance, previously defined emerging sectors over time were reclassified as established, additional coastal and maritime-related business activities became measurable, and new emerging sectors or subsectors were identified (cf. EC, 2018a, 2019a, 2020). Accordingly, there are many different views of what the Blue Economy is and thus, the issued definitions, for example by the OECD and the World Bank, may vary between each other as well as in comparison to the conception of the EC. Thus, deciding what the Blue Economy includes is a challenge in itself, given the difficulty of estimating the extent of coastal and ocean activities (e.g. distinguishing between inland and coastal tourism, or separating onland from offshore activities in the case of wind energy) and their direct and indirect impacts within the overall blue sector. Moreover, these challenges are exacerbated by the paucity of data for certain maritime sectors and the lack of comparability between EU member states' statistical data. Therefore, a clear distinction of the Blue Economy mainly depends on the sectors included and the extent to which indirect downstream and upstream effects can be identified and measured. Thus, decisions regarding the inclusion and exclusion of sectors and activities are crucial. In this context, it must be noted that a comprehensive evaluation of the Blue Economy, and thus Blue Growth, requires the estimation of the value of natural capital and the ecosystem services stemming from that capital. As emphasised by the EC, for a variety of reasons, it has proven impossible to provide such assessments (EC, 2018a, 2019a, 2020).

According to the most recent Blue Economy report from the EC, the EU-28 GDP was estimated at EUR 15,900 billion in 2018 (EUR 13,500 billion without the UK) and employment at 224 million people (194 million people without the UK), wherein the contribution of the Blue Economy established sectors to the EU-28 economy was 1.5% in terms of GVA and 2.2% in terms of employment. The underlying established sectors include (1) Marine Living Resources, (2) Marine Non-living Resources, (3) Marine Renewable Energy (Offshore Wind Energy), (4) Port Activities, (5) Shipbuilding & Repair, (6) Maritime Transport and (7) Coastal Tourism (EC, 2020). Consequently, the EC lists Port Activities most recently as a separate established sector next to Maritime Transport, with which such activities traditionally have to be associated, which underlines once more the important and special role of ports in the context of the EU Blue Growth Strategy as well as with respect to all Blue Economy sectors.

The established sectors can be described and outlined as follows (EC, 2020):

- The Marine Living Resources sector embraces the harvesting of renewable biological resources (i.e. primary sectors: Fishery and Aquaculture) as well as the processing and distribution. With 3% of the global production, the EU is the fifth largest producer of aquaculture and fishery products. Nonetheless, increased demand in Europe for seafood products and stagnation in the primary sector of Aquaculture have caused the dependency on third-country imports. Actually, the EU is the largest importer of seafood in the world, since its citizens consume more than twice as much as is produced inside the EU. In view of this, especially Aquaculture business, which is dominated by SMEs (about 90%), can help coastal communities to diversify their activities while alleviating fishing pressure, which may also help to preserve fish stocks. Moreover, in broader terms, the activities within the Marine Living Resources sector form an integral part of the emerging Blue Bioeconomy & Biotechnology sector, which includes any economic activity associated with the use of renewable aquatic biological biomass, e.g. food additives, animal feeds, pharmaceuticals, cosmetics, energy, etc. In sum, the proportion of the Marine Living Resources sector to the EU Blue Economy in 2018 was 11.5% of the jobs, 17.2% of the turnover and 9.6% of the GVA.
- The sector Marine Non-living Resources covers, on the one hand, the extraction of crude petroleum and natural gas, including the support activities (i.e. Offshore Oil & Gas) and, on the other hand, the operation of gravel and sand pits, the mining of clays and kaolin, and the extraction of salt and related support activities (i.e. Seabed Mining/marine aggregates). The exploitation of Europe’s seas and oceans for non-living marine resources has increased over the last decade, whereas the mature Offshore Oil & Gas subsector has been in decline for some years due to decreasing production and rising production costs, as well as the policy push towards clean energy. In addition, low oil prices have had some influence in making offshore facilities less economically viable. Nevertheless, about 80% of the oil and gas production within Europe takes place offshore, mainly in the North Sea (by the UK, Denmark, the Netherlands, Germany and Ireland) and, to a lesser extent, in the Mediterranean and Black Seas, while small offshore production in the Baltic Sea occurs along the Polish coast. In addition, the demand for marine aggregates dissolved in seawater, such as sand and gravel, used for construction purposes and for producing concrete, increased during the last decade, although this subsector is also known for high investment and operating costs. Overall, the contribution of the Marine Non-Living Resources sector to the EU Blue Economy in 2018 was 0.9% to jobs, 5.8% to turnover and 9.0% to GVA.

- The relatively young Marine Renewable Energy sector – in 2019 still classified as an emerging sector by the EC – incorporates all renewable energy sources that can be generated at sea, such as Offshore Wind Energy and Ocean Energy, as well as Floating Solar Photovoltaic. Currently, Offshore Wind Energy is the single commercial deployment within the Marine Renewable Energy sector, while this sector is generally also associated with high investment and finance costs. Moreover, this sector also has implications for the infrastructure of ports, where the assembly or portions of it may take place. Europe has about 90% of the world's total installed offshore wind capacity and thus clearly dominates the offshore wind market, with actions taking place mainly on the North Sea (by the UK, Denmark, the Netherlands, Germany and Belgium). Promising Ocean Energy technologies that are still in the R&D stage include Wave Energy, Tidal Energy, Salinity Gradient Energy and Ocean Thermal Energy Conversion (i.e. classified as emerging subsectors). In sum, the Offshore Wind Energy subsector, which is still relatively small, contributed 0.1% of the jobs, 0.5% of the turnover and 0.5% of the GVA to the total EU Blue Economy in 2018.
- Ports, as multi-activity transport and logistic nodes, play a crucial role in the development of the Blue Economy, as Port Activities provide the basic infrastructure and services for many other sectors, including Marine Living Resources, Marine Non-living Resources, Marine Renewable Energy, Maritime Transport, Coastal Tourism, Maritime Defence, etc. Hence, ports are the heart of the maritime industry, as they are the departure, entry and transfer points for all goods, services and persons transported by vessels. In 2018, Port Activities accounted for 11.0% of the jobs, 12.2% of the turnover and 16.1% of the GVA in the EU Blue Economy.
- The European Shipbuilding & Repair industry is an innovative, dynamic and competitive sector with a market share of around 15% of the global order book in terms of compensated gross tonnage and 34% in terms of value. Hence, the EU is the dominating player in the global shipbuilding industry. Its 300 shipyards, which generate an annual production value of about EUR 42 billion and employ more than 300,000 people, are specialised in complex and technologically advanced civilian and naval vessels, platforms and other hardware for maritime applications, such as cruise ships, offshore support ships, fishing boats, ferries, research vessels, dredgers and mega-yachts. In addition, the EU is the global leader in the production of high-tech, advanced maritime equipment and systems. Nevertheless, the domestic shipbuilding industry is in tough competition with producers from China and South Korea. In sum, the Shipbuilding & Repair sector accounted for 6.4% of the jobs, 7.9% of the turnover and 7.9% of the GVA in the total EU Blue Economy in 2018.
- Maritime Transport is essential to the global economy and the most carbon-efficient transportation mode in terms of each tonne transported per one kilometre, whereby, in sum, international maritime shipping accounts for about 3 to 4% of the annual global greenhouse gas emissions. However, the size and global nature of maritime shipping makes it necessary for the industry to reduce its environmental impact. Against this, the main developments in the sector are impelled by the steadily increasing ship sizes. Overall, in 2018, Maritime Transport was responsible for 8.2% of the jobs, 23.1% of the turnover and 16.3% of the GVA in the EU Blue Economy.

- The Coastal Tourism sector includes beach-based tourism and recreational activities, such as swimming, sunbathing and other activities for which proximity to the sea is pivotal, e.g. coastal walks and wildlife watching. Additionally, the Coastal Tourism sector incorporates water-based activities and nautical sports, such as sailing, scuba-diving and cruising. With half of the world's international tourist arrivals, Europe is the most-visited destination. Coastal Tourism is essential in many EU Member State economies, while the sector is mainly composed of SMEs and micro-enterprises (about 90% of enterprises with less than 10 people), which are particularly vulnerable to economic, financial and political changes, as witnessed during the COVID-19 pandemic. According to the latest figures from 2018, just over half (51.7%) of all the EU's tourist accommodations took place in coastal areas. In total, Coastal Tourism accounted for 62.0% of the jobs, 33.3% of the turnover and 40.6% of the GVA in the EU Blue Economy in 2018.

Accordingly, in terms of employment and GVA, the largest Blue Economy sector in the EU is Coastal Tourism. The same applies for generated turnover; only if the sectors Maritime Transport and Port Activities are considered together, the generated turnover is slightly higher than in the case of Coastal Tourism. Moreover, the sectors differ enormously regarding capital intensity, e.g. the Coastal Tourism sector compared to the Non-living Resources sector. Coastal Tourism is naturally quite labour-intensive and is mainly run by SMEs, often in the form of family businesses on the local level, and geographically distributed along the European coastline. This is also reflected by the greatest contribution to the EU Blue Economy in terms of employment and GVA. However, the contribution to GVA is substantially lower compared to employment. Against this, concerning the Non-living Resources sector, the Offshore Oil & Gas subsector is a highly capitalised industry that requires few employees per unit of output and is concentrated in specific geographical areas. Hence, the subsector is generally comprised of large firms. This is also mirrored by the respective figures concerning employment and GVA.

The emerging and innovative sectors in the context of the EU Blue Economy include some subsectors that are attributable to the Marine Renewable Energy sector (i.e. Ocean Energy, Floating Solar Energy and Offshore Hydrogen Generation), Blue Bioeconomy & Biotechnology, Marine Minerals (i.e. other minerals and metals in/on the seabed, e.g. manganese, tin, copper, zinc and cobalt), Desalination, Maritime Defence, and Submarine Cables (EC, 2020). Since these sectors are classified as emerging and thus, in most cases, are still not commercially deployed and their market and supply chains of inherent technologies not yet consolidated, they are not examined in more detail in this doctoral thesis. The exception is Blue Bioeconomy & Biotechnology, since this emerging sector, particularly through numerous initiated projects in the SBSR that target, among other things, the commercialisation of corresponding products and make the sector marketable, has assumed growing importance in the region in recent years.[2]

Regarding the geographical area of interest in the doctoral thesis, a rough metric overview of the past Blue Growth development—on the basis of the indicators of employment, turnover and GVA—differentiated according to the established Blue

[2] The following are some of the most recent or ongoing projects from the SBSR that focus on Blue Bioeconomy & Biotechnology: Baltic Blue Biotechnology Alliance+, Smart Blue Regions, FucoSan, WaSeaBi, Macro Cascade, MacroFuels, GoJelly, BONUS CLEANAQ, BONUS FLAVOPHAGE (Submariner Network for Blue Growth EEIG, n.d.).

Economy sectors concerning the adjacent EU countries of the SBSR (i.e. Denmark, Germany, Lithuania, Poland and Sweden) is given in Appendix 2.[3] According to Appendix 2, the established sectors for which data was available, but in some cases was limited, were differentiated as Aquaculture, Coastal Tourism, Fishery, Seabed Mining, Offshore Oil & Gas, Marine Renewable Energy (Offshore Wind Energy), Shipbuilding & Repair, and Maritime Transport (incl. Port Activities). As the Blue Growth development indicator, the Compound Annual Growth Rate (CAGR) was applied on the basis of the figures from 2009 and 2018.

Concerning employment, the sectors Fishery (−1.6%), Offshore Oil & Gas (−3.6%) and Shipbuilding & Repair (−0.9%) show negative CAGRs on the basis of the period of consideration (2009 to 2018). Thus, all other sectors exhibit positive growth development (Coastal Tourism = 2.5%, Seabed Mining = 3.3%, Marine Renewable Energy = 2.2%, Maritime Transport = 2.6%), whereas especially the Aquaculture sector displays high growth development between 2009 and 2018 (19.3%), which can be traced back mainly to expansions in Poland. Similar to the European level, in terms of employment, the Coastal Tourism sector is the largest Blue Economy sector, followed by Maritime Transport (incl. Port Activities), concerning the adjacent EU member states of the SBSR (cf. Appendix 2).

Regarding generated turnover, only the CAGR of the Offshore Oil & Gas sector is negative in the period of consideration (−6.8%). Accordingly, all other sectors show positive CAGRs (Aquaculture = 2.8%, Coastal Tourism = 4.1%, Fishery = 1.9%, Seabed Mining = 5.2%, Shipbuilding & Repair = 2.9% and Maritime Transport = 4.1%), while the Marine Renewable Energy sector indicates the greatest annual growth development from 2009 to 2018 (23.8%). Nevertheless, this result from the Marine Renewable Energy sector has to be treated with caution, since data is currently available only for Denmark. However, in terms of turnover generation, Maritime Transport (incl. Port Activities) is by far the largest Blue Economy sector, concerning the adjacent EU member states of the SBSR. This circumstance is not so grave on pan-European level, if Maritime Transport and Port Activities are summarised (cf. Appendix 2).

In the case of GVA, the Offshore Oil & Gas sector also shows a negative CAGR in the period 2009 to 2018 (−12.8%). Conversely, all the other established Blue Economy sectors exhibited a positive Blue Growth development in the past (Aquaculture = 4.1%, Coastal Tourism = 4.1%, Fishery = 1.7%, Seabed Mining = 4.2%, Shipbuilding & Repair = 2.8% and Maritime Transport = 2.2%), whereas the Marine Renewable Energy sector recorded the greatest annual growth development (32.2%). However, as already mentioned, this result has to be treated with caution due to limited data availability. Similar to the case of generated turnover, Maritime Transport (incl. Port Activities) shows the largest GVA and thus proves its dominating role in the adjacent EU countries of the SBSR, which contrasts with the situation on the pan-European level, in which Coastal Tourism is clearly the largest sector of the Blue Economy in terms of GVA—even if Maritime Transport and Port Activities are summarised (cf. Appendix 2).

[3] Please note that data incorporated in Appendix 2 is on total country bases (i.e. NUTS 0 level), since data on the NUTS 1 to 3 level – at the time of writing the doctoral thesis – was not available or accessible for all the established Blue Economy sectors, while also on a country basis (i.e. NUTS 0 level) for the sectors Seabed Mining, Offshore Oil & Gas, as well as Marine Renewable Energy (Offshore Wind Energy), only limited data was available, which limits the sectors' comparability (i.e. especially comparisons with the sector Marine Renewable Energy). Hence, the given overview (including calculated sums and CARGs) goes beyond the SBSR.

Comprehensive scientific studies on Blue Growth are lacking. Indeed, research on Blue Growth is developing but is still not widespread and convincing (Vreÿ, 2019). This can be traced back, among other factors, to differing definitions and the evolutionary character of the term Blue Economy, as well as to missing comprehensive socioeconomic databases that cover appropriate historic data of multiple regions and layers concerning the diversified maritime activities that are associated as "blue". Hence, research that focuses on sector-integrative Blue Growth and thus covers the Blue Economy and its underlying sectors as a whole are rather rare. More precisely, apart from the recent annual reports from the EC about the Blue Economy development, with incomplete data, scientific studies on Blue Growth development measurements, or those that target the assessment of the future potential in a regional development context, do not exist. Instead, the academic research is dominated by a focus on single, or in a few cases coupled, Blue Economy sectors or subsectors (Mayén Cañavate et al., 2019), when studying Blue Growth:

- Aquaculture (e.g. Brugère et al., 2019; Moffitt & Cajas-Cano, 2014; Ndiaye et al., 2019; Sarà et al., 2018),
- Blue Bioeconomy & Biotechnology (e.g. Albrecht & Lukkarinen, 2020; Carrasco et al., 2018; Raimundo et al., 2018; Vigani, 2020),
- Coastal Tourism (e.g. Mayén Cañavate et al., 2019; Neva et al., 2020; Tegar & Gurning, 2018),
- Fishery (e.g. Boonstra et al., 2018; Chen & Zhou, 2020; Da-Rocha et al., 2019; Garza-Gil et al., 2019; Hadjimichael, 2018; Hilborn & Costello, 2018; Mulazzani et al., 2016; Niiranen et al., 2018; Said & MacMillan, 2020; Saviolidis et al., 2020),
- Seabed Mining (e.g. Carver, 2019; Childs, 2020; Glover et al., 2018),
- Offshore Oil & Gas (e.g. Legorburu et al., 2018; Murray et al., 2018; Sedlar et al., 2019),
- Marine Renewable Energy (e.g. Kerr et al., 2018; Lavidas et al., 2020; Rodríguez-Rodríguez et al., 2016; Young, 2015),
- Shipbuilding & Repair (e.g. Alempijević & Kovačić, 2019; Papathanasiou et al., 2018),
- Maritime Transport (e.g. Niavis et al., 2017; Rijkure, 2017; Seisdedos & Carrasco, 2020; Zhang & Ravesteijn, 2019).

1.2 Peculiarities and Challenges of Small and Medium-sized Ports

From the previous theoretical insights, it is evident that ports are the key entities within the EU Blue Growth Strategy, as they provide the basic infrastructure and services for the diversified Blue Economy sectors. Thus, ports are the pivotal drivers of Blue Growth, whereas developmental modifications of their operations and processes have far-reaching spill-over effects on the business activities of the other maritime sectors and beyond. According to Rozmarynowska and Oldakowski (2013), 66% of all BSR ports are small and medium-sized ports, which handle less than two million tonnes of cargo per year. Since these ports form the majority and are an essential source of entrepreneurial spirit and innovation, they represent an important object of investigation, especially in the context of Blue Growth. Thus, there is a need to support small and medium-sized ports in their crucial role of generating economic growth, triggering innovations, attracting new investments and businesses, enabling clusters to evolve, ensuring employability and fostering social integration (EC, 2013e, 2013f, 2017b, 2018b; Eurostat, 2018a; Global Innovation Index, 2018; Prause et al., 2018). In the academic literature, small and medium-sized ports as a central research subject has been sparsely in focus. However, a few research studies exist and reveal some peculiarities and problems that are characteristic of small and medium-sized ports.

A common problem is that small ports in the BSR are regularly not able to secure their own financing that is desperately needed for sustainable development, which is additionally aggravated by the circumstance that they are often neglected by policy makers on the EU, regional and even local levels (Rozmarynowska & Oldakowski, 2013). This lack of financing can have serious consequences, especially since empirical studies underline that port infrastructure investments foster economic development. Hence, the lack of investment resources leads to negative externalities, which, in the long term, undermine the competitiveness of a region as a whole (Rodrigue & Schulman, 2013; Jouili, 2016).

Notteboom (2007) noted as well that the cargo market share of small and medium-sized ports, as well as their influence on the market, is likely to continue to be small. Furthermore, he stressed that smaller ports will face difficulties in challenging the established large load centres, since small and medium-sized ports as potential entrants in the container handling market typically do not fulfil the requirements concerning maritime accessibility and terminal layout. Thus, it is suggested that small ports target the tackling of major issues that are related to the hinterland network accessibility and their lack of experience in stakeholder-related procedures linked to terminal projects, as well as their lower cargo-generating and cargo-binding potential.

Other researchers highlight that small ports do not have the resources and knowledge to implement the techniques and concepts that were developed for large ports (Olesen et al., 2014a). In addition, small ports do not have the same economies of scale as their larger counterparts to support developments that are more complex. A general problem is also that small and medium-sized ports are challenged to engage in better supply chain development and integration (ibid.). Simkins and Stewart (2015) emphasise that ports have control over their facilities but must compete for funding to improve them. Furthermore, they pinpoint challenges for small and medium-sized ports that are related to hinterland access. Margarino (2014) also noted this fundamental problem and identified the main reason as the lack of necessary funds.

Olesen et al. (2014a, 2014b) stressed that small and medium-sized ports are lacking in elementary strategic concepts. Hence, especially in terms of capturing and improving the hinterland, there is an urgent need for approaches that support small and medium-sized ports in the process of choosing the appropriate strategic direction and collaboration initiatives. Additionally, ports are service providers and therefore have specialised resources that need to be optimally used. According to Castillo-Manzano et al. (2013), efficient supply chains need to be established by small and medium-sized ports to ensure that freight is shipped smoothly and more cost effectively, which, in turn, will allow the ports to be more competitive.

Moreover, small and medium-sized ports in the BSR suffer from lower cargo volumes, missing smart specialisation, out-dated infrastructure, inadequate investments and the absence of new business models that could contribute to Blue Growth. In addition, small ports in the BSR have a common and high interest in digitalisation, but they lack knowledge of Industry 4.0, IoT, Blockchain, etc. and the inherent potentials (Philipp et al., 2018). Accordingly, smaller ports have no overview of the already existing wide range of

ICT solutions and current trends that facilitate smart integration into supply chains as well as optimisation of the infrastructure and transport services, e.g. digital cargo handling, automated tracking, security harmonisation and Big Data management among the different port handling, forwarding and servicing systems. Hence, in order to keep pace with the fast-changing market environment and customer needs, small and medium-sized ports, as dormant gateways of economic and social interactions for regional development and growth, have to develop digitalisation strategies as well as push ahead initiatives and sustainable measures.

1.3 Digitalisation, Novel Technologies and Smart Ports

The growing interest in digitalisation and related novel technologies has evolved over the last decade especially. Digitalisation is often regarded as the saviour in terms of managing the challenges of the increasing globalisation, competition, environmental issues and customer-oriented supply chain focus. Digital technologies, such as safe and secure distributed databases (e.g. Blockchain) and other so-called data-enabled technologies, are already distributed in diverse industry sectors, such as manufacturing and IT, as well as in transport and logistics (e.g. Gerlitz, 2015, 2017; Philipp et al., 2019a; Prause, 2015a, 2019; Prause & Atari, 2017).

In general, digitalisation implies a revolutionary change of the industrial and economic system (Decker & Blaschczok, 2018). 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 third industrial revolution (Horvat et al., 2018). Accordingly, Industry 4.0 is the digital transformation process of the manufacturing industry, which is enabled and impelled by the rapid technological development (Rajnai & Kocsis, 2018).

To keep up with the rapid pace of change induced by such digital technologies, small ports have to initiate actions. However, in comparison to their larger counterparts, small ports receive only minor financial support, e.g. with regard to the CEF (EC, 2013b, 2013c). This circumstance puts even more pressure on the smaller ports in terms of their access to and utilisation of digital technologies. Large ports, such as Rotterdam or Antwerp, have been applying digital databased technologies for several years and continue to rely on the expansion of these advanced and rapidly developing technologies, which promise security, process optimisation and sustainability as they merge into huge digital networks and platforms. In doing so, they connect and converge the physical and digital worlds (i.e. machines, devices and humans). The main goal of the application of such novel digital technologies is to optimise economic performance and use of energy, to reduce the consumption of resources and the production of waste as well as to improve the service portfolio. Indeed, seaports rely on large transport and logistics companies when it comes to the development and implementation of innovative technology applications. Since major transport companies, such as Maersk, are already intensively investing in digital technologies that are regarded as the enablers for the digital transformation in the context of Industry and Logistics 4.0[4], it is important that small and medium-sized ports also take the opportunity to apply these novel technological solutions in order to integrate themselves in a sustainable way into the global supply chains. If adequate opportunities are not identified and exploited, competitive disadvantages will arise in the long run, which will be difficult to catch up (Philipp et al., 2018).

Especially in the context of the novel visionary idea of smart ports, the investigation of digitalisation possibilities and the application and integration of novel technologies becomes more and more important. The brainchild of a smart port development is associated with an innovative endeavour in which the focus is on improving the competitiveness of the port and facilitating entrepreneurial collaboration between different port stakeholders in order to achieve the horizontal and vertical integration of supply chains (Douaioui et al., 2018). According to Yang et al. (2018), a smart port can be defined as a fully automated port in which all devices are connected via the IoT. Thereby, a network of smart sensors, actuators, wireless devices and data centres make up the key infrastructure of a smart port, which allows port operators or authorities, respectively, to provide both traditional and new services more efficiently. Consequently, the major drivers in the aspired smart port development are increased productivity and efficiency. As a result, various technological applications are tested, implemented and used sustainably within the digital transformation towards smart port development (ibid.). Following Gardeitchik et al. (2017), the development of ports into smart ports can be differentiated by five stages: (1) the port has no automation at all, (2) includes individual automation, (3) all port-involved stakeholders aim to integrate their systems to achieve better communication, (4) the port and the hinterland players are connected through one single digital environment, (5) each port is connected to its environment, and all ports are connected globally with each other (i.e. smart port stage). Therefore, in the final smart port stage, the port will be completely connected via a communications network and fully integrated in its environment (i.e. all stakeholders of the industry) as well as with other ports and logistics actors around the globe. Accordingly, without the inclusion of small and medium-sized ports, this innovative idea remains unachievable. Until now, the idea of a smart port is only a vision. Nevertheless, it is expected that the usage and implementation of new digital technologies will contribute substantially to the aspired development towards smart ports. However, there is currently a lack of concepts and models for measuring the digital performance of ports. Without such tools, it is impossible to audit the digital status of ports and to derive a concrete strategic roadmap for the digital transformation towards sustainable smart port development.

Port performance measurement (PPM) is widely employed in practice and research. Principally, PPM concepts incorporate so-called Key Performance Indicators (KPIs), which, due to their defined target-oriented purpose, are often relabelled as PPIs (e.g. de Langen et al., 2007; Talley 1994). In this regard, one of the most prominent frameworks is the one

[4] The implementation of the Industry 4.0 vision "without Logistics 4.0 is just unthinkable as the globalisation of the economy without logistics networks that span the world" (Delfmann et al., 2018, p. 2). Hence, Industry 4.0 can only become reality if logistics is able to supply production systems with the necessary input factors according to the right time, quality and place requirements (Hofmann & Rüsch, 2017). According to Wehberg (2016), Logistics 4.0 – also known as smart logistics – is defined as developing, designing, managing and realising change-oriented networks of object flows (e.g. goods, information, values) based on pattern recognition, generalisation and self-organisation, enabled through the usage of new technologies and innovative services.

from the United Nations Conference on Trade and Development (UNCTAD) in 1976 (UNCTAD, 1976), which is often concerned as the origin source in the frame of newly developed PPM concepts. However, for over a half of century, most PPM concepts had been developed in order to measure the performance of container ports and container transport logistics (CTL) (e.g. Tongzon, 1995; Talley, 2006; Cullinane et al., 2005; Wang et al., 2003, etc.). Therefore, it can be noted that past research efforts focused mainly on operative performance measurement in larger ports that handle containers (Twenty-foot Equivalent Unit – TEU) as the primary cargo type, which, specifically in the European context, usually represent core ports in the sense of the TEN-T. Impelled by the growing interest in digitalisation, recent PPM concepts exhibit novel indicators, such as IT System, Databases, Networks, Integrated EDI for Communication, Integrated IT to share Data, etc. (e.g. Ha et al., 2019), but still exclusively were elaborated on and applied in the context of container ports. Besides this target group limitation, there exists no PPM framework that was created for the purpose of measuring the digital performance of ports. Accordingly, the existing PPM concepts in theory and practice do not consider the wide range of innovative technologies that are regarded as the enablers for the digital transformation towards smart port development.

With regard to the existing research gap of missing digital performance measurement instruments for ports, the large variety of developed digitalisation and Industry 4.0 readiness indexes and maturity models in recent years appears to be a usable and promising research trend. Digital and Industry 4.0 readiness indexes are well-known on the macro level, where they are applied to measure and compare the digital performance of different nations, for instance: the Networked Readiness Index (NRI) from the World Economic Forum (n.d.), the Industry 4.0 Readiness Index from the consultancy company Roland Berger (n.d.), the Digitisation Index (DiGiX) from BBVA Research (n.d.) and the Digital Economy and Society Index (DESI) published by the EC (n.d.). In contrast to this, of particular interest are the numerous digital and Industry 4.0 readiness indexes and maturity models that have been developed in recent years for analysing and measuring the digital performance and Industry 4.0 readiness of companies (micro level). According to Rajnai and Kocsis (2018), digital and Industry 4.0 readiness index assessments and maturity models can support management in establishing the roadmap for the digital transformation of their company by auditing the current digitalisation status of benchmarked firms. In general, most of the digital and Industry 4.0 readiness indexes and maturity models on the micro level that have been proposed in theory and practice target the evaluation of the performance of manufacturing firms, due to the fact that they are the main target group in the context of Industry 4.0. However, the overall logistics sector is relatively unaffected by digital and Industry 4.0 readiness indexes and maturity models. Thus, Decker and Blaschczok (2018) claim that their study was the first to elaborate a digital readiness analysis in the logistics sector. The conducted literature review that underlies the doctoral thesis confirmed this, and further proved that, so far, no digital readiness index and/or maturity model exists for ports. Accordingly, in the light of the lack of PPM concepts and studies that focus on digital performance measurement in ports, the significant number of digitalisation and Industry 4.0 readiness indexes and maturity models developed in recent years, which concentrate primarily on the manufacturing sector, at least appear to be a suitable reference point for the development of a digital auditing tool for ports. Hence, based on a conducted literature review of digital and Industry 4.0 readiness indexes and maturity models that have been proposed and applied in science and practice, the digital technology roadmap for ports is presented in Table 1.

Table 1. *Digital Technology Roadmap for Ports*

Digital technologies & solutions	Source
Smart ERP System	Kroll et al., 2016; Leyh et al., 2016; Weber et al., 2017; Decker & Blaschczok, 2018; Demeter et al., 2018; Singapore, 2018
Smart WMS System	Kroll et al., 2016; Decker & Blaschczok, 2018; Geissbauer et al., 2016
Smart PCS System (incl. Electronic SCM System)	Kroll et al., 2016; Leyh et al., 2016; Demeter et al., 2018; Geissbauer et al., 2016; Dennis et al., 2017; Rockwellautomation, 2014
Web-based Communication Platform	Decker & Blaschczok, 2018; Geissbauer et al., 2016
Mobile Data Access for Employees	Rajnai & Kocsis, 2018; Decker & Blaschczok, 2018; Demeter et al., 2018; Craffert et al., 2014; Geissbauer et al., 2016; Impuls (n.d.)
Mobile Data Access for Customers	Rajnai & Kocsis, 2018; Decker & Blaschczok, 2018; Geissbauer et al., 2016; Impuls (n.d.)
IoT (incl. Machine-to-Machine-Communication)	Rajnai & Kocsis, 2018; Bogner et al., 2016; Leyh et al., 2016; Weber et al., 2017; Basl, 2018; Decker & Blaschczok, 2018; Geissbauer et al., 2016; Dennis et al., 2017; Singapore, 2018; Impuls (n.d.)
Cloud Computing (SaaS, PaaS, IaaS)	Horvat et al., 2018; Rajnai & Kocsis, 2018; Bogner et al., 2016; Kroll et al., 2016; Leyh et al., 2016; Weber et al., 2017; Basl, 2018; Decker & Blaschczok, 2018; Demeter et al., 2018; Geissbauer et al., 2016; Singapore, 2018; Rockwellautomation, 2014; Innovation Centre for Industry 4.0, (n.d.); Impuls (n.d.)
Localisation Technologies (GPS, RFID, etc.)	Rajnai & Kocsis, 2018; Decker & Blaschczok, 2018; Demeter et al., 2018; Jodlbauer & Schagerl, 2016; Geissbauer et al., 2016; Beuth, 2016; Impuls (n.d.)
Sensors (Humidity, Temperature, etc.)	Rajnai & Kocsis, 2018; Kroll et al., 2016; Leyh et al., 2016; Weber et al., 2017; Basl, 2018; Decker & Blaschczok, 2018; Jodlbauer & Schagerl, 2016; Schuh et al., 2017; Geissbauer et al., 2016; Singapore, 2018; Beuth, 2016; Impuls (n.d.)
Big Data & Predictive Analytics (e.g. for Maintenance, etc.)	Rajnai & Kocsis, 2018; Bogner et al., 2016; Leyh et al., 2016; Weber et al., 2017; Basl, 2018; Decker & Blaschczok, 2018; Jodlbauer & Schagerl, 2016; Schuh et al., 2017; Back et al., 2015; Geissbauer et al., 2016; Dennis et al., 2017; Singapore, 2018; Innovation Centre for Industry 4.0, (n.d.); Impuls (n.d.)
Blockchain (incl. Smart Contracts)	Decker & Blaschczok, 2018; Singapore, 2018
Artificial Intelligence (AI)	Basl, 2018; Decker & Blaschczok, 2018; Schuh et al., 2017; Singapore, 2018
Robotics	Kroll et al., 2016; Basl, 2018; Decker & Blaschczok, 2018
Drones (Air, Land, Water)	Decker & Blaschczok, 2018; Dennis et al., 2017
Autonomous Solutions (Terminals, Cranes, Vehicles) – CPS (Cyber-Physical Systems)	Basl, 2018; Decker & Blaschczok, 2018; Schuh et al., 2017; Geissbauer et al., 2016; Singapore, 2018
Digital Twinning, Augmented & Virtual Reality (incl. Simulation)	Bogner et al., 2016; Kroll et al., 2016; Leyh et al., 2016; Weber et al., 2017; Basl, 2018; Decker & Blaschczok, 2018; Jodlbauer & Schagerl, 2016; Schuh et al., 2017; Back et al., 2015; Geissbauer et al., 2016; Dennis et al., 2017; Singapore, 2018; Innovation Centre for Industry 4.0, (n.d.)

Source: Article II

1.4 Blockchain and Smart Contracts

Among all the novel technological evolutions, Blockchain is one of the most promising (Kouhizadeh & Sarkis, 2018). Much interest in this innovative, but still not widely integrated, technology has arisen, especially since information intermediary levels can be reduced or fully replaced. As a result, Blockchain and Smart Contracts contribute to decreased transaction and enforcement costs, while ensuring high data security. In accordance with this, scientific studies have shown that this technology greatly enables efficiency and productivity increases (e.g. Martinez et al., 2019; Nelson et al., 2017). However, the potential Blockchain implementation in ports has not been examined in the scientific research (Koh et al., 2020). Indeed, there exist port-related projects in practice (e.g. TradeLens by IBM and Maersk, launched in 2018, and the start-up T-mining in Antwerp, which was founded in December 2016); however, the focus, in addition to the creation of information pipelines and the building of a paperless trade, is primarily on automating processes in large container ports, since automation in the case of standardised units such as TEUs is much easier to implement, e.g. in comparison to dry bulk goods. Thus, private enterprises are currently leading the Blockchain progress, while scientific research and governmental institutions still lag far behind (Chang et al., 2020), although academic research studies on Blockchain have grown considerably since 2017 (Bukhari, 2020; Müßigmann et al., 2020).

The first Blockchain was designed by Satoshi Nakamoto[5] in 2008, with the objective of generating digital coins, the control of which is distributed under the independent participating actors in a virtual network (i.e. decentralised) instead of a central institution (e.g. government or bank) with complex bureaucracies. The preliminary first field of application – the cryptocurrency Bitcoin – became fully operational in January 2009, with the first successfully completed mining operation (Fridgen et al., 2018; Nakamoto, 2008; Pinna et al., 2018; Swan, 2015). Therefore, Blockchains have their origins in the financial sector. They are often described as open and distributed ledger systems that allow participants or users via address account (i.e. alphanumerical code) and private key to process transactions quickly with each other in specific cryptocurrencies and without an interposed third party (e.g. intermediary, middleman, broker or agent). Moreover, a Blockchain forms a decentralised network of trust due to its inherent high data security characteristics, in which paperwork and physical signatures are superfluous (Chuen, 2015; Gallay et al., 2017; Liao & Wang, 2018; Manski, 2016; Swan, 2015). Due to the improved information accessibility and the reduction of risks and layers of middlemen, resulting in declining transaction costs, the competitiveness and efficiency of smaller, independent users in particular (e.g. entrepreneurs and SMEs) can be increased (Wu, 2018). Blockchains – as shared networks or infrastructures – are differentiated into public and private, as well as permission-less and permissioned. A public Blockchain, which is generally permission-less, is open to everyone (regularly anonymous participants), whereas a private Blockchain network is accessible only to chosen participants who are usually known. In a permission-less Blockchain network, such as Bitcoin, with the proof-of-work (PoW) consensus algorithm[6], all users – also known as nodes – are allowed to mine[7], while in a permissioned Blockchain, this right to validate transactions and

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[5] Satoshi Nakamoto is a pseudonym. Until now, no one knows the identity of the person or group of persons behind the pseudonym.

[6] There exist different consensus algorithms (incl. combinations) that come into effect within Blockchains. Best known is the PoW consensus algorithm, followed by proof-of-stake (PoS). Each consensus algorithm has its strengths and weaknesses. For instance, Ethereum – with the cryptocurrency Ether, the most prominent after Bitcoin – has shifted from the PoW to the PoS consensus algorithm, which can be traced back mainly to the huge energy demand caused by the PoW consensus algorithm. Hence, there exist many different consensus algorithms and related modifications that are applied in practice and discussed in scientific literature, e.g. practical byzantine fault tolerance (PBFT), proof of elapsed time (PoET) and delegated proof-of-stake (DPoS).

[7] The validation procedure or creation of new blocks poses a process which varies depending on the applied consensus algorithm. For instance, in the case of Bitcoin with the PoW consensus algorithm, this process is called mining, where in the peer-to-peer network, a computationally hard problem of determining a hash key for the new block is solved, which then incorporates, among other things, a timestamp next to the transaction data, the respective hash code of the previous block, its height (associated progressive number), as well as the IP address of the first miner, who created the new block (Pinna et al., 2018). As usual in a competition, the winner takes it all, here the first or fastest, respectively, miner who created the new block receives a reward in the form of new (mined) crypto-coins (Wang & Liu, 2015). Before the proposed new block is attached to the already existing chain of blocks, the newest block is checked in the network. Against this, for instance in the case of the PoS consensus algorithm, blocks are forged or minted, which induces the calling of the validators as forgers. Here, basically, a validator is selected randomly according to its stake, whereby several methods were created to ensure a fair selection within the network

create new blocks is exclusively available to certain participants, whereas access – similar to a private Blockchain – is regulated (Fridgen et al., 2018; Kouhizadeh & Sarkis, 2018). Besides the decentralised network character, the term Blockchain refers to a data structure, an ordered sequence of blocks, each containing data about a variable number of validated transactions, which are cryptographically chained (i.e. one by one) by the inclusion of the respective hash values and cryptographic signatures, which makes it impossible to amend a former already validated and integrated block of the chain without the network members' consensus (García-Bañuelos et al., 2017; Lansiti & Lakhani, 2017; Pinna et al., 2018). This unique data structure is permanently visible (i.e. transparent), verifiable and stored among a network of machines or computers (García-Bañuelos et al., 2017). To summarise, the Blockchain technology exhibits some special features which represent its key advantages compared to other respective information technologies (Fridgen et al., 2018; Kouhizadeh & Sarkis, 2018): (1) decentralisation, (2) transparency and auditability (through a tamper-proof process history), and (3) data integrity, security and immutability.

Smart Contracts[8] – also known as digital contracts or e-contracts – extend the Blockchain applications and thus have the potential for even wider use (Gallay et al., 2017; L'Hermitte et al., 2018; Swan, 2015; Wu, 2018). Smart Contracts are transactional protocols or scripts that encompass the business rules and terms of contracts. They are stand-alone programmes and one of the simplest forms of automation with if-then-else functions that are run on the top of Blockchains, where they are embedded in digital codes with software. Hence, a Smart Contract is self-executable and performs the negotiated terms of contract agreements to which the respective participants previously agreed (Liao & Wang, 2018). Thus, Smart Contracts are able to read from and write on the Blockchain, and enable, whenever certain actions or transactions occur, further actions or transactions to be automatically executed (García-Bañuelos et al., 2017). Smart Contracts are transparently stored on the Blockchain and thus are shared with their digital record and signature among the authorised contractual participants, as well as secured from distortion, revision, tampering and deletion due to the special features of the Blockchain technology (Liao & Wang, 2018). Accordingly, the usage of Smart Contracts building upon the Blockchain technology further removes the value of formerly involved third parties (e.g. intermediaries, middlemen, brokers or agents, such as governments, banks, lawyers, etc.) in diverse business activities, which additionally reduces transaction costs and fosters the efficiency and redesign of complex business processes.

The usage of Blockchain technology for cryptocurrencies, such as Bitcoin, Ether, Litecoin and MaidSafeCoin, has inspired scientific research in the financial service sector in recent years. Established financial institutions are challenged by innovative start-ups that try to address novel issues related to financial transactions, stock options, etc. However, the unique characteristics of the Blockchain technology, and especially the possibility for the execution of Smart Contracts, have promoted ideas for even greater

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(e.g. randomized block selection, coin age-based selection). For the validation of the transactions and creation of the new block, the forger receives a transaction fee (Alketbi et al., 2018).

[8] Nick Szabo originally described the term Smart Contracts in his scientific article "Smart Contracts: Building Blocks for Digital Markets", in 1996. At that time, his idea of Smart Contracts was only a vision, but with the rise of the Blockchain technology, the designers (namely: Vitalik Buterin, Gavin Wood and Jeffrey Wilcke) of Ethereum made the vision come true in 2015 (Buterin, 2014; Wu, 2018).

application areas in different markets that go far beyond the financial sector. In this context, agriculture (e.g. Kamilaris et al., 2019; Lin et al., 2017, 2018), energy (e.g. Albrecht et al., 2018; Andoni, 2019; Mengelkamp et al., 2018), government (e.g. Ølnes, 2016; Ølnes et al., 2017), healthcare (e.g. Griggs et al., 2018; Mettler, 2016; Pilkington, 2017; Wong et al., 2018; Zheng et al., 2018), manufacturing (e.g. Ko et al., 2018; Li et al., 2018) and real estate (e.g. Shedroff, 2018; Veuger, 2017) are only some examples of the modern application fields of Blockchain technology. Nevertheless, in particular, SCM has the potential for extensive Blockchain applications (Kouhizadeh & Sarkis, 2018). For instance, Casado-Vara et al. (2018) described the implementation of Blockchain technology, including Smart Contracts, in an agriculture supply chain. Tian (2016) highlighted an agri-food supply chain traceability system based on RFID and Blockchain technology. Korpela et al. (2017) described how supply chain integration empowered by Blockchain in conjunction with Smart Contracts could achieve disruptive transformation in digital supply chains. However, apart from these and further examples in the scientific literature, the current research on the adoption of Blockchains and Smart Contracts in supply chains is still limited (Liao & Wang, 2018), despite the advantages of authentication of traded products, disintermediation and thus the decrease in transaction costs (Nowiński & Kozma, 2017). Moreover, bearing in mind that ports play an especially integral role within many supply chains, there is an urgent need for action to fill the research gap concerning Blockchain integration in ports.

1.5 Theoretical Setting

To explain economic growth and regional performance, different theories emerged over the time. One of the varying research streams focuses on the role of clusters; however, this field rather hosts different approaches and concepts, and thus it still cannot be regarded as a discrete theory (Vorley, 2008). The origins can be traced back to Marshall (1890), to Piore and Sabel (1984), up to Krugman (1991), whereas the nascent theory experienced a renaissance through the contributions of Porter (2000, 1990). In his well-known cluster concept, Porter (2000, p. 16) highlighted the regional aspect of a cluster by defining it as “a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities”. Hence, the performance and competitiveness of a cluster depends on its internal characteristics in the form of commonalities and complementarities. In addition, a cluster is determined by its external environment (i.e. geographical setting), while the majority of the related literature also stresses the spatial aspect by explaining why a group of companies emerge in a particular place and why they are bound to this specific place (Philipp et al., 2019b). An often mentioned advantage of the development of clusters is that they allow companies to be more productive and innovative due to the higher degree of interactions with other companies and stakeholders in their environment, than in the case of isolation (ibid.). Moreover, according to zu Köcker (2009), the cluster approach enables the achievement of a competitive advantage since it decreases the entry barriers for new business creations in comparison to other sites. Building upon these fundamental insights, many research studies have investigated different types of clusters and showcased the numerous advantages that arise for companies that have settled or emerged within clusters, for instance, high-tech clusters (e.g. Bresnahan & Gambardella, 2004; Chandrashekar & Bala Subrahmanya, 2019; Pan et al., 2019a), financial service clusters (Pan et al., 2019b; Wan et al., 2018; Zhang & Chen, 2013), etc., while de Langen (2004) was the first to develop an innovative framework to analyse the performance of seaport clusters. According to Stavroulakis et al. (2020), maritime clusters are of particular significance for regional and national economic development. Maritime clusters are important not only in relation to the connected hinterland but also to the whole economy in acting as a gateway for maritime transport. Furthermore, Shi et al. (2020a) highlighted the future challenge for maritime clusters to continuously upgrade their processes to feature ecologically friendly ports, supply-chain hubs and resource allocation centres. In recent studies, researchers have recognised as well the importance of the cluster concept in the context of Industry 4.0, and thus digital transformation. In this regard, clusters are viewed as incubators and test labs of the digital transformation due to the fact that innovations are more likely to emerge and become more quickly implemented within clusters (Hervas-Oliver et al., 2019; Götz, 2020, 2019; Götz & Jankowska, 2017; Lazzeretti et al., 2019; Shi et al., 2020b).

The endogenous growth theory is another well-known theory that provides a link between economics and geography (Vorley, 2008). This is one of the most prominent theories that is dominated by innovation-based growth models. Accordingly, the endogenous growth theory builds on innovation processes as the central driver for productivity growth. According to the theory, the economic growth and prosperity of nations or regions is achieved more by internal activities and interactions within a system than by external forces (Romer, 1994, 1986). Hence, the actions or interactions of entities, such as firms or individuals, in a region determine economic growth (Aizenman & Marion, 1993). Two major streams have developed within the endogenous growth theory. According to Romer (1987, 1990), the main engine for economic growth is technological and thus innovation progress, which is induced by physical capital and associated with new knowledge generation on the labour side, as well as innovative capacity. Against this, Lucas (1988) places emphasis on human capital as the crucial factor for innovation and thus economic growth. Therefore, in contrast to the growth model of Solow (1956), the endogenous growth theory explains economic growth in terms of technology transformations that are induced by innovations arising from individuals' reactions to market incentives. Romer (1990) stated that especially R&D activities from the private sector provide the sustainable impulse for technological change, which results from the continuous vertical enhancements of intermediate products and services or the horizontal extension of the intermediate product and service variety. Correspondingly, in particular, policies that appear in the form of investments in human capital will stimulate long-term economic growth. Accordingly, government interventions should target to set the fruitful frame and sound conditions for self-induced technological change, i.e. deliver incentives for innovation generation and entrepreneurial activities. For instance, a recent study by Castellacci et al. (2020) showed that e-skills – capabilities that are associated with the usage and development of digital technologies –, as an important aspect of human capital, improve regions' ability to gain access to and replicate external advanced knowledge, as well as to create new industrial paths or technological specialisations. Therefore, governmental investments in the development of e-skills can have strong benefits and may make it possible to create new technological areas. A study from Friesenbichler and Hölzl (2020) revealed that a larger shares of industries with high digitalisation intensities are related to a higher share of high-growth firms, which suggests that the technology base of a region positively affects firms' growth prospects. This corroborates that high-growth firms are more prevalent when economic structures offer novel technological and market opportunities. Consequently, in the context of the thesis, it can be postulated that in this era of Industry 4.0, the implied technological change in the sense of the endogenous growth theory has to be regarded as the digital transformation process in companies, as well as ports. Hence, the need in the private sector for digitising processes, (intermediate) products and services as a push effect will generate economic growth. Moreover, concerning the Maritime Economy in the SBSR, it can be further postulated that the digital transformation of ports towards smart ports will facilitate Blue Growth in the region.

Another important cornerstone within the theoretical setting of the doctoral thesis is the transaction cost theory. Simply summarised by Arrow (1969, p. 48), transaction costs are the "costs of running the economic system". Hence, the transaction cost theory builds upon the presence of costs that occur for the usage of a market, which, in a natural manner, represent the additional burdens of operations for firms and other market participants (Coase, 1937; Williamson, 1996, 1985a, 1975). This is because all economic activities are accompanied by transactions, for instance, any exchange of goods or provision of services, which are usually fixed by contracts (Williamson, 1985a). According to Williamson (1985a), transaction costs are differentiated as ex ante contract costs (e.g. costs for searching, negotiation, drafting, etc. until a contract is fixed) and ex post contract cost (e.g. costs for execution, enforcement of the contract terms, concluding calculations, etc.). The central key dimensions of transaction costs are defined by asset specificity, uncertainty and frequency, which determine the choice of a market (Chiles & McMackin, 1996; Williamson, 1991, 1985a). Linked to transaction costs is the important decision of firms regarding make-or-buy (Walker & Weber, 1984; Williamson, 1985b). According to the theory, decreasing transaction costs lead to an enhancement of economic efficiency, since capital and labour become freed. For instance, electronic marketplaces, such as Alibaba, Amazon and Check24, are operated via the Internet and thus represent digital business models, which, at the same time, are often regarded as the output of business model innovation. Their introductions improved the connection of market actors through reduced intermediary levels as well as increased communication and transparency (Wang et al., 2008). Induced by lower transaction costs, products could be offered and purchased at lower prices. Furthermore, and as a consequence, some retailers and other distributors were driven out of the market. Bearing this circumstance in mind, Yigitbasioglu (2014) stated that the lack of trust as well as uncertainties in the course of transactions are some of the major reasons for organisations' intentions to adopt different digital technologies, such as cloud computing services. However, taking a more holistic view, it can be postulated that a central aim of digitalisation, and thus the digital transformation process, is to eliminate or reduce certain transaction costs. The rationale for this can be traced back to the fact that the different digital technologies and solutions are applied, among other things, for the improvement of information flows. Consequently, technologies in the context of Industry 4.0 improve the communication between market participants within a system. On the other hand, many novel digital technologies also ensure the automation of information and data exchange as well as specific operational actions and financial transactions. Therefore, digital transformation inevitably results in the elimination or reduction of intermediary levels in different business segments, as well as spurs the redesign of traditional and complex business structures. Hence, lower manual works and improved information flows lead to the elimination or lowering of certain transaction costs and, as a result, increase economic efficiency.

The high relevance of resources and capabilities has its roots in the famous resource-based view theory. This theory builds upon the inference that companies are heterogeneous, since they do not possess homogenous resources, which opens room for differential corporate strategies (Barney, 1986; Amit & Schoemaker, 1993; Peteraf, 1993). Hence, the resources a firm controls are decision-relevant (Solesvik & Westhead, 2010; Penrose, 1959; Dierickx & Cool, 1989). According to Barney (1991), a firm's resources can provide a sustainable competitive advantage if they are valuable, rare, imperfectly imitable and non-substitutable, which collectively form the term VRIN. These resources can be tangible (physical assets, such as machines, plants, etc.) or intangible (non-physical assets, such as reputation, skills, knowledge, etc.) (Penrose, 1959; Conner, 1991). Capabilities have a special significance, since, on the one hand, for instance in the context of employees (e.g. IT capabilities), they may constitute a VRIN resource, but, on the other hand, in the spotlight of the theory, they are regarded as the firm's capacity to deploy its resources – often in combination or bundled – by using organisational processes to generate competitive advantage (Amit & Schoemaker, 1993; Leonard-Barton, 1992; Makadok, 2001; Teece et al., 1997; Wade & Hulland, 2004; Wernerfelt, 1984). The utilisation and development of resources is regarded as dynamic, since resources change over time because of innovative managerial behaviour, and it is the usage of the resources that enables the achievement of competitive advantage, not the resources *per se* (Coates & McDermott, 2002). Hence, learning and knowledge generation are crucial for the development and effective usage of capabilities and resources (Prahalad & Hamel, 1990). Accordingly, the resource-based view theory is about the nature of firms—in contrast to the transaction cost theory, which targets to explain why firms exist (Lockett et al., 2009). In light of the resource-based view theory, a number of researchers have highlighted the significance of IT capabilities for the creation of superior profit (Chen et al, 2014; Nwankpa & Datta, 2017; Nwankpa & Roumani, 2016; Wade & Hulland, 2004). In accordance with this, in the context of the digital transformation, Nwankpa and Datta (2017), as well as Nwankpa and Roumani (2016), further emphasise that companies with special IT-based resources, knowledge and skills are more likely to evolve from pure information systems applications to specific digital technologies, such as Big Data analytics. Therefore, with respect to the resource-based view theory, firms with superior IT capabilities are able to cope better with digital transformation through the redesigning of their business processes, products and services (ibid.).

According to the established theoretical framework, the following can be postulated: The digital transformation in companies, including ports, is an entrepreneurial venture and strategic process that implies technological and organisational changes concerning processes, services and products, which is fuelled and accompanied by the interactions with other market players and stakeholders, as well as the resulting knowledge generation and innovations. In this way, and through the deployment of unique resources and capabilities that result in competitive advantages, digital transformation has the potential to contribute substantially to sustainable economic growth or Blue Growth.

2 Methodology

The following chapter sets out the philosophical considerations and the derived research methodology, including a presentation of the applied research design, data collection activities and analysis measures. This incorporates the exposition of selected research methods that were deployed for answering the defined research questions in an appropriate way. Moreover, the constructive discourse with the main target groups contains respective definitions and limitations that, in some ways, confine naturally the reach of the research results.

2.1 Philosophical Considerations

The research paradigm followed in the doctoral thesis is positivism, which is based on the thesis of naturalism. Positivism considers reality as persisting of discrete events which can be observed by the human senses. Under this paradigm, knowledge is derived from experience, while concepts are used to describe knowledge (Macionis & Gerber, 2010). Accordingly, the preceding philosophical considerations that guide the choice of methodology are grounded, on the one hand, on the shallow or naïve realist ontology and the epistemology of empiricism. However, the reflected philosophy of science is twofold, as the philosophical considerations of the doctoral thesis, on the other hand, are based on idealist ontology and the epistemology of social constructionism. Hence, the doctoral thesis balances between these two sets of considerations, which is justified by the described research problem and related research questions, as well as by the lack of research studies on the topic and thus the exploratory nature of the dissertation.

The shallow realist ontology – also known as naïve realist, empirical realist or actualist – manifests an external reality which consists of objects and events only that are perceived, as well as governed, by natural and social laws. Therefore, the challenge for science is to discover and describe the patterns and sequences of the observations. According to the epistemology of empiricism, knowledge is produced using the human senses and comes from the objective perception of the external reality and its representation in scientific concepts and theories (Blaikie, 2007; Given, 2008).

In contrast, according to idealist ontology, differences exist between natural and social phenomena, whereby actions or interactions always refer to meaning-giving processes. Hence, the related interpretations of individuals constitute respective realities. Thus, this ontology accepts the possibility of multiple realities, as different groups or individuals perceive and understand the world in different ways. Social constructionism relates to intersubjectively shared knowledge, whereas the focus is on the collective generation and transmission of meaning. Thence, knowledge is derived, or rather constructed, from individuals' realities, and from interpretations of observed individuals' actions and situations (Blaikie, 2007; Cohen et al., 2018; Given, 2008).

2.2 Research Design

Due to the lack of profound research studies on the doctoral thesis topic and thus, the exploratory nature of the dissertation, the doctoral thesis employs mixed methods research (Creswell & Creswell, 2017), which simultaneously does justice to the dualism of the philosophical considerations. More precisely, the research strategy of methodological triangulation is applied, in which research is designed by a combination of multiple methods (i.e. quantitative and/or qualitative) (Given, 2008). Following Denzin (2006), a full understanding of a complex single phenomenon or of a contextual set of interrelated phenomena under investigation requires the use of more than one method, since otherwise there is no way of judging the reactive and biasing effects of observations and methods. According to Altricher et al. (2005), triangulation is considered as a method for contrasting and comparing different accounts. As such, alternative perceptions are compared, which helps in the interpretation of a phenomenon and the development of practical theory. Hence, where different perspectives agree with one another, the interpretation can be considered as more credible. In general, there is consensus that both "within methods" triangulation and "between methods" triangulation increase the reliability and validity, or dependability, credibility and transferability of the research findings (O'Donoghue & Punch, 2003). For this reason, both triangulation levels were performed in the doctoral thesis, in order to overcome the problem of "method-boundedness" caused by single-method approaches. Furthermore, the application of the triangulation concept provided a more comprehensive understanding of the research problem and allowed the research questions to be more rigorously addressed. On the other hand, this induced as well the triangulation of data sources and analysis measures. However, the triangulations were always performed respecting the economic viability concerning research costs, since serious disadvantages of the triangulation method are the increased effort of a very rich data collection and the increased time required to analyse and interpret the data (Altricher et al., 2005; Cohen et al., 2018; Given, 2008).

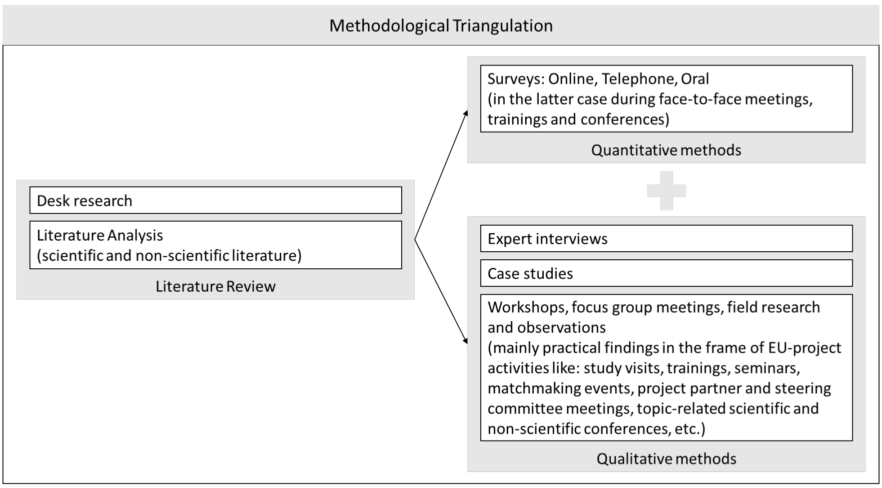

***Figure 1*.** Research Design
Source: Compiled by author

Hence, the data collection and analysis measures referred to the qualitative and quantitative method approaches (Creswell & Creswell, 2017; Diekmann, 2007; Döring & Bortz, 2016; Kromrey, 2013; O'Leary, 2017; Schnell et al., 2004). The elaboration of the surveys, as well as subsequent pre-tests and data collection activities, were executed according to the principles of Diekmann (2007), Döring and Bortz, (2016), Kromrey (2013), O'Leary (2017), Rüdiger et al. (2011) and Schnell et al. (2004). The structured and semi-structured expert interviews that delivered the quantitative and qualitative data were prepared, performed and analysed by following the guidelines of Kvale (2008) as well as Miles and Huberman (1984). Furthermore, case studies were conducted according to Creswell and Creswell (2017), Stake (1995) and Yin (2017, 2009, 1989).

Each study was initiated by a desk research and comprehensive systematic literature analysis according to all specifically tackled topics. Thereby, the literature review activities referred to both scientific (i.e. materials from journals, conferences, symposiums, etc.) and non-scientific (e.g. project and market reports, policy regulations and guidelines, spot prices, etc.) literature. Figure 1 summarises the research design of the doctoral thesis.

2.3 Data Collection

In the framework of the doctoral thesis, the theory-based and practice-related research builds upon empirical data from surveys (online, telephone, oral), structured and semi-structured expert interviews, case studies, workshops, focus group meetings, field research and observations that were elaborated, implemented and conducted in the course of the following EU projects:

- Connect2SmallPorts – INTERREG V A, 2017 plus 2018–2021 (Seed-money and subsequent main project)
- INTERMARE South Baltic – INTERREG V A, 2017–2021
- CSHIPP – INTERREG V B, 2018–2020
- GoLNG – INTERREG V B, 2016–2019

2.3.1 Target Groups, Stakeholders and Validators

In the frame of the conducted data collection activities that took place between March 2017 and January 2020, the primary target groups included, on the one hand, the Maritime Economy from the SBSR in general, and, on the other hand, small and medium-sized seaports from the SBSR in particular. Hence, the scope of empirical data collection activities was geographically narrowed to the SBSR and its contiguous EU countries, namely Denmark, Germany, Lithuania, Poland and Sweden, or more precisely, the eligible catchment area of the INTERREG South Baltic programme (INTERREG South Baltic, n.d.).

Building upon a desk research and literature review, the decision was made to define the Maritime Economy according to the Blue Economy term from the EC, with respect to the EU Blue Growth Strategy (EC, 2020, 2019a, 2019b, 2017a, 2014, 2012; cf. sub-chapter 1.1). Accordingly, as outlined in sub-chapter 1.1, the focus was on companies from the sectors Aquaculture, Blue Bioeconomy & Biotechnology, Coastal Tourism, Fishery, Seabed Mining, Offshore Oil & Gas, Marine Renewable Energy (Offshore Wind Energy), Shipbuilding & Repair, and Maritime Transport.

The target audience of small and medium-sized seaports was defined in analogy to the TEN-T classification. Thus, comprehensive seaports that are considered medium-sized ports and non-TEN-T seaports that are regarded as small ports were identified and selected. On the basis of these characteristic and geographical limitations, Appendix 3.1 gives an overview of the identified main target group. Thereby, during the selection procedure, attention was paid only to the economically most important small and medium-sized ports in the SBSR, since for even smaller ports, historical data on a secondary basis is missing, and thus they are not listed in publicly available statistics and databases. For the desk research, port websites (incl. websites from national or supranational port organisations), the database of Eurostat (2018b), TEN-T regulations from the EC (EC, 2013b), the Baltic Port List from the University of Turku (Saurama et al., 2008), as well as the INTERREG South Baltic programme information about the eligible catchment area (INTERREG South Baltic, n.d.) were used. Hence, more small ports exist in the SBSR than indicated in Appendix 3. However, since no or inconsistent information and data was available for some smaller ports, the major focus was on the 28 small and medium-sized ports highlighted in Appendix 3. Moreover, a closer look into the cargo statistics, as shown in Appendix 3.2, exemplifies that container handling plays a subordinate role for small and medium-sized ports in the SBSR. This is also true in the case of larger ports and concerning the entire BSR, in comparison to the North Sea.

Besides these target groups (i.e. Blue Economy in general and small and medium-sized ports in particular), the doctoral thesis was carried out through expertise exchange and involvement of project experts and interest groups. Especially the interactions with stakeholders delivered essential insights into business practices and the status quo of digitalisation and environmental issues in the environment of maritime logistics and, specifically, small and medium-sized ports. Furthermore, the logistics and seaport-related scientific and non-scientific conferences, in which the author participated, spurred the information exchange with other stakeholders. Hence, the interaction and collaboration with numerous different stakeholder groups allowed for a more comprehensive perspective on the topic. Lastly, for verification and validation of the elaborated research findings (particularly the developed models and case studies), the author selected and involved stakeholders during workshops that were of particular individual topic-relevance; among these were policy makers; terminal and port operators/authorities; maritime infrastructure and spatial planners; port and shipping centres and organisations (incl. shipping companies, ship-owners and operators) as well as forwarders; international organisations and institutions that relate to port-related supply and value chains; shipyards; academic and research institutions; and regional industry representatives.

2.3.2 Instruments and Measures

According to the presented research design, the doctoral thesis builds upon secondary and primary data that was collected and produced through desk research and subsequent literature analyses, surveys, expert interviews, case studies, workshops, focus group meetings, field research and observations. Each partial study was initiated with desk research for the identification and acquisition of secondary data, as well as literature and knowledge concerning the status quo of the topics under investigation.

In total, two surveys were developed for the primary data gathering. The objective of the survey "Future Potential of Maritime Economy in South Baltic Sea Region" in the frame of the Intermare South Baltic project was to identify and analyse the future potential of the Blue Economy in the SBSR, along with the trends that currently affect this potential or will in the near future. In contrast, the aim of the survey "Digital Auditing in Small Ports", in the course of the Connect2SmallPorts project, was to analyse and index ports according to their performance and readiness regarding digitalisation. Both surveys were developed, implemented and monitored by the author. First, the surveys were implemented and launched as online surveys by using the web-based application tool Unipark. In both cases, pre-tests were conducted with different participants from the SBSR. The pre-tests to the online surveys were conducted to obtain confirmation regarding content validity from both project partners (Intermare South Baltic project and Connect2SmallPorts project) as well as the corresponding market actors. Furthermore, the major focus of the pre-tests was to guarantee the clarity, value and importance of the survey items. Thus, the pre-tests primarily ensured the verification of the comprehensibility of the questions and supported the improvement of the surveys regarding the composition and orchestration of the questions. Hence, the related empirical data collection activities were initially or completely online-based, in which access to the online surveys was provided via specific links to the websites. In the frame of the online survey "Digital Auditing in Small Ports", the author of the thesis was solely responsible for the acquisition of participants, whereby the invitation to the online survey reached the target group via e-mails (incl. two reminders). The same procedure was conducted in the course of the online survey "Future Potential of Maritime Economy in South Baltic Sea Region", while two previous selected project partners (Intermare South Baltic project) from Lithuania and Poland assisted the data collection process; thus, the author was solely responsible for the acquisition of participants from Denmark, Germany and Sweden. Furthermore, in the case of this latter survey, at the end of the data collection phase – in order to achieve an adequate response rate in some target countries – companies were contacted additionally via telephone and during face-to-face meetings, training events or conferences (i.e. telephone and oral survey). Regarding the survey "Future Potential of Maritime Economy in South Baltic Sea Region", in total, 133 companies completed the questionnaire between November 2018 and June 2019. In contrast, the online survey "Digital Auditing in Small Ports" will be accessible and regularly updated during and beyond the project lifetime (Connet2SmallPorts) until the end of 2026. Consequently, access to the questionnaire is granted for interested port representatives via the following link: https://ww2.unipark.de/uc/Connect2SmallPorts-DRIP/. Between December 2019 and January 2020, in total, 33 ports completed the online survey, whereby not all of them are from the SBSR. Nonetheless, in the frame of the doctoral thesis, the answers of the representatives from five ports only were selected for further in-depth case studies. The two online surveys are presented in Appendix 4.

Additionally, the author collected primary data through 39 face-to-face, telephone and IT-based structured and semi-structured expert interviews with top-level managers from seaports, experts from the logistics and IT sector, project experts, scientists and stakeholders. The expert interviews took place between November 2018 and January 2020 and comprised open-ended and close-ended questions. All interviews lasted about one hour and were recorded and transcribed.

The case studies were primarily developed on the basis of data from the expert interviews or surveys with supplementary expert interviews. Moreover, generated knowledge from workshops, focus group meetings, field research and observations complemented some of the case studies. The related practical findings and relevant information were gained from a broad field of project activities, such as project partner and steering committee meetings, trainings, matchmaking events, logistics and open seaport-related conferences with project interest groups. Thereby, the focus group meetings within the Connect2SmallPorts project were performed for a stronger target-oriented investigation of particular topics of interest.

Lastly, some workshops within the Connect2SmallPorts project were used as well to receive validation and verification by the primary target group and stakeholders concerning the research results. Thus, these workshops were conducted to test the developed models as well as to ensure their applicability and transferability. Consequently, the objective was to receive constructive criticism and finally approval and confirmation regarding the elaborated models and case studies. These events provided fruitful discussions and allowed for an enlarged and comprehensive understanding of individual perceptions and needs. Subsequently, further workshops and trainings within the implementation of the Connect2SmallPorts project were used to deliver insights and best practices from the research outputs to a wider audience.

2.4 Data Analysis

The selection of the data analysis techniques was driven by the defined research objective and questions, as well as the respective philosophical considerations and thus the selected research methods. An overview of the interplay between the research questions, research methods and data analysis methods in the frame of the doctoral thesis is provided in Table 2.

RQ1 was addressed in Article I. Building upon the received data from the survey, the CAGR was used to measure the future growth potential of the Blue Economy in the SBSR. In addition, to investigate the impacts of the potential drivers on the sustainable development of the blue sector, descriptive statistical data analysis was performed.

RQ2 was tackled in Articles II and III. First, an extensive literature review was conducted in Article II. In addition to the literature review and the analysis and study of the relevant theories and concepts, the research was complemented by qualitative expert interviews. In the frame of the subsequent data analysis, qualitative content analysis was performed to identify the overarching themes. Hence, based on the identified, analysed and synthesised literature findings about PPMs (incl. PPIs), as well as digital and Industry 4.0 readiness indexes and maturity models, plus findings from the expert interviews that were conducted in the course of the EU project Connect2SmallPorts, the digital auditing tool for ports (i.e. digital readiness index for ports – DRIP) was conceptualised. In Article III, the so-called DRIP was applied and tested as well as subsequently validated. Thereby, the DRIP was initially implemented as an online survey. On the basis of the received primary data from the online survey and the subsequent descriptive statistical analysis, five ports were selected for in-depth case studies. As a result, additional expert interviews were performed with top-level managers from the five selected ports. Thus, the developed case studies build upon the analysed survey data as well as complementary information from the expert interviews. Conclusively, these case studies were processed and presented through benchmarking. Alongside these case studies, through qualitative content analysis of the literature findings and input from the expert interviews, the strategic graduation model towards smart port development (i.e. digital maturity model) was elaborated. In this case, the strategic graduation model towards smart port development was presented to the five ports during additional expert interviews. Received suggestions for improvements were taken into account and finally led to the confirmation of the concluding model by the port representatives.

RQ3 was addressed in Articles IV and V. In Article IV, a qualitative research approach was chosen due to the lack of scientific studies concerning Blockchain integration in ports (cf. sub-chapter 1.4). Hence, qualitative expert interviews and complementary workshops, focus group meetings, field research and observations delivered the needed data and insights for the identification of the common functionalities of sustainable Blockchain and Smart Contract usage. Thus, through qualitative content analysis of the received data and an analysis of potentials, as well as subsequent narrative retelling, the two case studies were elaborated. In the frame of Article V, the research results were based on expert interviews, observations and practical findings, which were condensed and narratively retold by the author through qualitative content analysis. The output is the LBG MEC business model that was presented using the Business Model Canvas from Osterwalder and Pigneur (2009). Lastly, a comparative analysis with ULSFO was carried out within a case study.

Table 2. *Applied Research Methods & Data Analyses to address Research Questions*

Research Question	Article	Research Method	Data Analysis
RQ1: What is the predicted future Blue Growth potential of the Maritime Economy in the SBSR, and what are the impacts from the Digitalisation, TEN-T regulations and IMO Sulphur directives on the sustainable performance of the blue sector?	I	Survey (online, telephone, oral)	Forecast analysis (CAGR), descriptive statistical analysis
RQ2: How is it possible to assess the digital performance and strategically safeguard the digital transformation in ports?	II	Literature review, expert interviews	Qualitative content analysis, synthesis of overarching themes
	III	Survey (online), expert interviews → case studies	Descriptive statistical analysis, benchmarking, qualitative content analysis
RQ3: How do Blockchain and Smart Contracts improve efficiency in ports and their ecosystems?	IV	Expert interviews, workshops, focus group meetings, field research and observations → case studies	Qualitative content analysis, analysis of potentials
	V	Expert interviews, observations → case study	Qualitative content analysis, comparative analysis

Source: Compiled by author

3 Results

In this chapter, the main findings of the doctoral thesis are presented. The research results are showcased in chronological order with respect to the defined research questions – starting with the future Blue Growth potential and the impacts from the Digitalisation, TEN-T regulations and IMO Sulphur directives, to the digital transformation towards smart ports, up to the Blockchain and Smart Contract applications in ports and their ecosystems.

3.1 Blue Growth and Impacts from Digitalisation, TEN-T and Sulphur Regulations

In the first step, the results of a conducted forecast analysis are showcased concerning the future Blue Growth potential of the Maritime Economy in the SBSR. Additionally, in the frame of the second part, the findings from a trend analysis are presented for the detection of the main driver that is expected to have the greatest impact on the future Blue Growth in the SBSR. The presented results jointly serve to answer the indicated RQ1.

3.1.1 Future Blue Growth Potential in South Baltic Sea Region

For the purpose of measuring the future growth potential of the Maritime Economy in the SBSR, representatives from the blue sectors were asked to estimate their company's turnover growth rates (in %) on the basis of the overall time horizon 2019 to 2023 for the following markets: Regional, National, BSR, Europe, Africa, Asia, Australia, North America and South America. Thereby, it is evident that the nine investigated markets can be summarised into categories (1) domestic markets and (2) international markets. At the same time, the aggregation of the results concerning the six continental markets allows concrete deductions about the overall future growth potential of the Maritime Economy and each single sector. The determined CAGRs structured according to the domestic and international markets are showcased in Figures 2 and 3 (Article I).

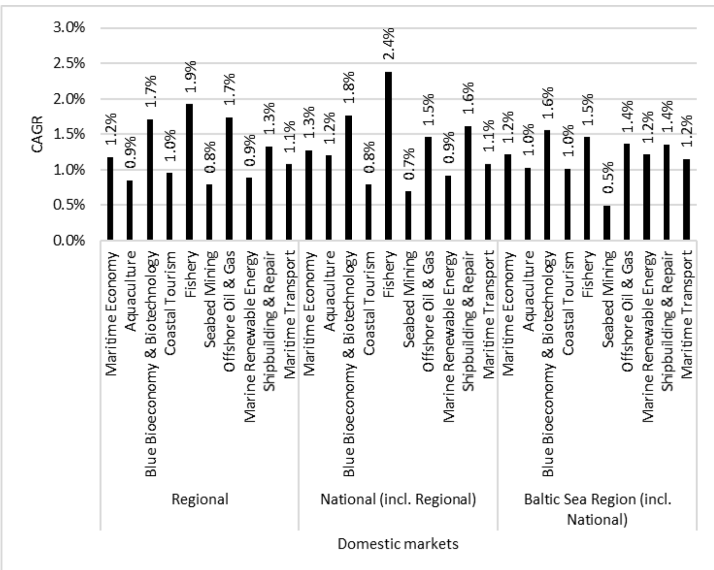

Figure 2. CAGRs on Domestic Markets
Source: Article I

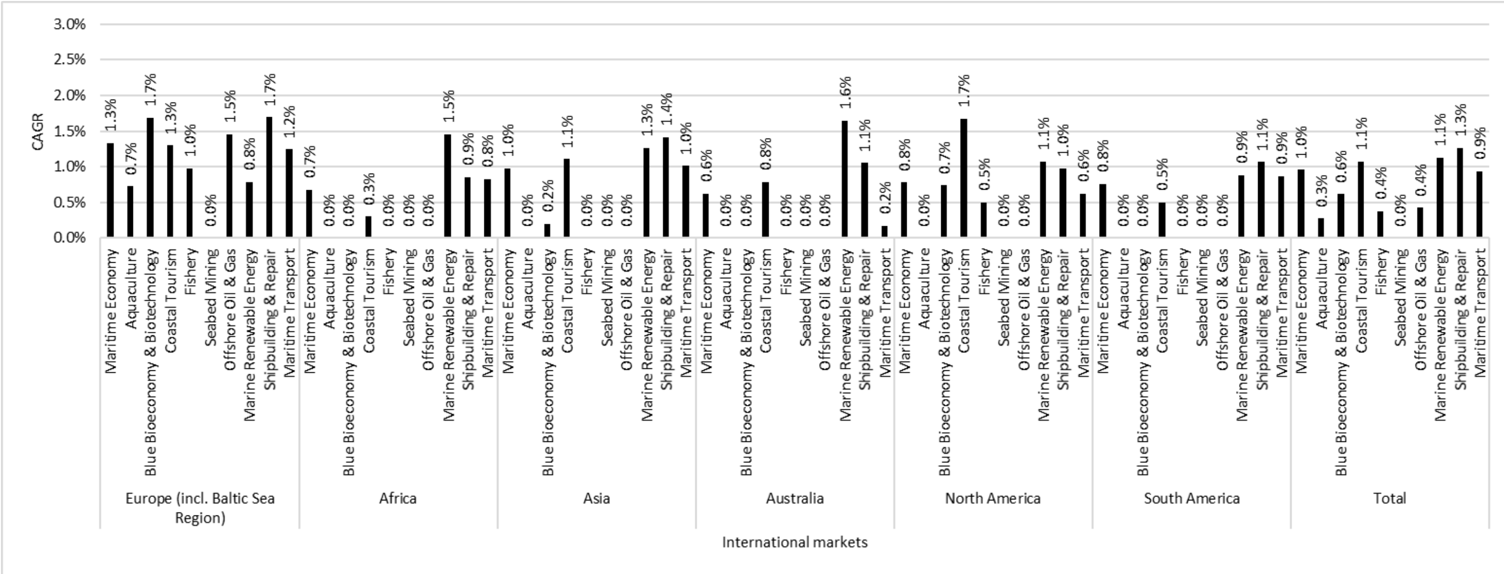

Figure 3. CAGRs on International Markets
Source: Article I

The study carried out that for the Maritime Economy in the SBSR as a whole, domestic markets and the European market are more important than all other international markets. In addition, and in answer to the first part of RQ1, the future growth potential of the Blue Economy in the SBSR as 1.0% has to be evaluated as moderate and not very promising. This is reflected as well by the results concerning the underlying sectors, the majority of which exhibit fairly low future growth potential (Article I).

In the case of the sectors Aquaculture, Coastal Tourism, Seabed Mining, Marine Renewable Energy and Maritime Transport, the domestic markets have low or, in some cases, moderate future growth potential. In contrast, the other four sectors Blue Bioeconomy & Biotechnology, Fishery, Offshore Oil & Gas, and Shipbuilding & Repair show greater future growth potential in the domestic markets (Article I).

Moreover, the study from Article I revealed that for the sectors Aquaculture, Blue Bioeconomy & Biotechnology, Fishery, Seabed Mining, and Offshore Oil & Gas, the domestic markets are associated with higher growth prospects (i.e. greater future growth potential) than the international markets. However, the two sectors Aquaculture and Seabed Mining have to be highlighted, as international markets seem to play a subordinate role, and likewise in the domestic markets, the expected future growth potential is relatively low. In contrast, comparatively greater future growth potential in international markets was detected for the sectors Coastal Tourism, Marine Renewable Energy and, particularly, Shipbuilding & Repair (Article I).

Therefore, on the basis of the projected Blue Growth potential, it can be implied that the need for actions is evident for companies from the sectors Aquaculture, Blue Bioeconomy & Biotechnology, Fishery, Seabed Mining, and Offshore Oil & Gas. Since the overall future growth potential of Maritime Transport is evaluated as rather low, this sector has to be subsumed as well to the blue industries with generally dimmed growth prospects. Hence, on first glance, it can be derived that for a systematic fostering of Blue Growth in the SBSR, actions need to be initiated that aim to promote these six sectors especially (i.e. Aquaculture, Blue Bioeconomy & Biotechnology, Fishery, Seabed Mining, Offshore Oil & Gas, and Maritime Transport), as their forecasted growth potential is substantially lower in comparison to the other sectors of the Blue Economy in the SBSR (Article I).

3.1.2 Impact from Digitalisation, TEN-T and IMO Sulphur Regulations on Blue Growth

For the analysis of potential drivers that have some kind of effect on the future business development, representatives of the Maritime Economy from the SBSR were further asked to evaluate the strength and direction (i.e. positive or negative) of the influences from the (1) Digitalisation, (2) TEN-T and (3) SECA Regulations & Global Sulphur Cap. These potential drivers were selected because, in the current research landscape, they represent widely discussed themes in the context of the maritime industry (e.g. Atari & Prause, 2017; Barros, 2005; Gerlitz et al., 2018; Henesey & Philipp, 2019; Olaniyi et al., 2019,, 2018b; Philipp et al., 2019a, 2018). Thereby, a Likert scale was administered, with "(−2) Very negative", "(−1) Rather negative", "(0) Neutral", "(+1) Rather positive" and "(+2) Very positive". The results are highlighted in Figure 4 (Article I).

In answer to the second part of RQ1, the results show that Digitalisation is expected to have the greatest impact on the future development of the Blue Economy in the SBSR. In addition, the aggregated results concerning the Blue Economy show that all three influences have a positive sign, which suggests that Digitalisation, TEN-T and the SECA Regulations & Global Sulphur Cap represent promoting factors of Blue Growth in the SBSR. The fact that Digitalisation forms the most important driver was also detectable among all the investigated Blue Economy sectors (Article I). This finding is astonishing, taking into account that the CEF provides an overall investment volume for the TEN-T development in Europe of around EUR 24.2 billion for the current planning period (2014–2020) (EC, 2013c), and that the annual total costs of SECA compliance for the BSR alone amount to around EUR 553 million (Prause & Olaniyi, 2020).

However, the expected influences from TEN-T, as well as the SECA Regulations & Global Sulphur Cap, vary among the sectors. Within the sectors Aquaculture, Blue Bioeconomy & Biotechnology, Fishery and Seabed Mining, the companies expect actually even no and/or negative economic impacts through the TEN-T and/or SECA Regulation & Global Sulphur Cap. In contrast, firms of the Maritime Transport sector estimate that the TEN-T will have a greater positive influence on the future business development than the SECA Regulation & Global Sulphur Cap. Nevertheless, since the strongest positive impact on the regional economic development is awaiting in the case of Digitalisation, prospective measures should aim at this significant main driver in order to foster Blue Growth in the SBSR (Article I).

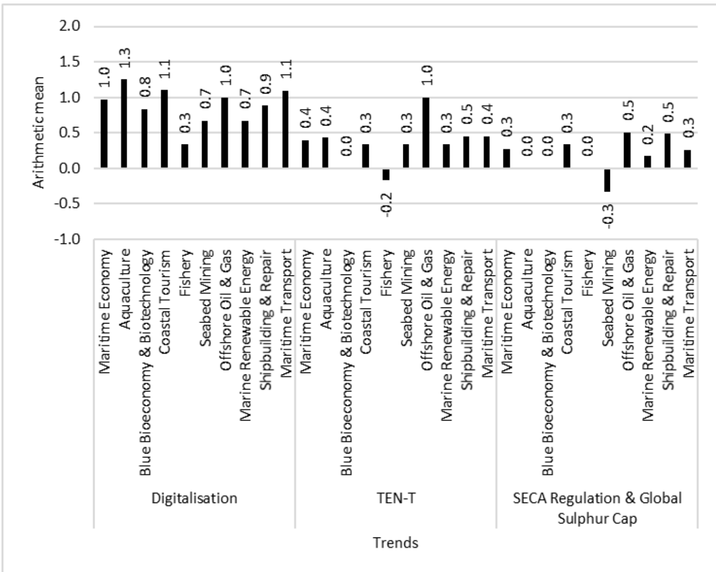

Figure 4. Impacts from Digitalisation, TEN-T and IMO Sulphur Directives
Source: Article I

3.2 Digital Transformation towards Smart Ports

From the research results of the preceding section, it can be deduced that for facilitating smart regional growth in the SBSR, the central focus should be, among other things, on the Maritime Transport sector and digitalisation, which was identified as the strongest driver for Blue Growth (cf. sub-chapter 3.1). Setting the research focus on Maritime Transport is underlined by the identified dominant role of this Blue Economy sector in the adjacent EU countries of the SBSR (cf. sub-chapter 1.1). On the assumption that these insights also apply to the factual catchment area of the SBSR and, as stressed by Beifert et al. (2015), the region is characterised by a particularly strong social and economic dependency, Maritime Transport represents the most important sector of investigation in the context of Blue Growth in the SBSR. Concerning the Maritime Transport system, three key players can be highlighted: (1) shipping companies, (2) seaports and (3) freight forwarders (Caliskan & Ozturkoglu, 2018). Hence, the global movement of freight is not realisable without the complementary actors to merchant shipping – the seaports. Ports are the main logistics hubs for commercial operations worldwide (Rodrigue & Schulman, 2013). Therefore, in order to promote Blue Growth in the SBSR via the Maritime Transport sector, particular emphasis must be laid on ports. Furthermore, as stressed by the EC (2020), ports play the crucial role in the generation of Blue Growth, as they provide the basic infrastructure and services for the various Blue Economy sectors, whereby emanating spill-over effects go regularly beyond the Maritime Economy, as ports are the key service providers for the entire economy (cf. sub-chapter 1.1).

As the findings from the literature review revealed, there is a lack of research studies that focus on small and medium-sized ports (cf. sub-chapter 1.2). This circumstance, as well as the fact that 66% of all BSR seaports are small and medium-sized ports (Rozmarynowska & Oldakowski, 2013), plead for a stronger concentration and inclusion of this target group (incl. their specific characteristics and perspectives) in further research activities that target to foster spatially inclusive and comprehensive Blue Growth in the SBSR. Moreover, taking into account that digitalisation was detected as the main driver for Blue Growth in the SBSR, the need emerges in the context of ports for the application of an approach to analyse their digital performance and readiness. As the results of a further literature review showed, the digital performance measurement in ports has not been researched so far, which represents a clear research gap (cf. sub-chapter 1.3). In addition, as further deduced from the literature review findings, the digital transformation process in ports is targeted to reach the highest digitalisation level, which is characterised by the smart port vision, in which ports are optimally connected with their environment and all ports globally (Gardeitchik et al., 2017). This once again behoves a focus on and inclusion of small and medium-sized ports in the further research process, since otherwise, the innovative idea of smart ports remains unachievable. Apart from this, the roadmap for the sustainable development and reachability of this final digital transformative stage is still unclear and thus, until now, represents another central research gap in the scientific literature (cf. sub-chapter 1.3).

Accordingly, in the following section, the DRIP model is presented, which targets to close the identified scientific research gaps (cf. Article II). Additionally, in the further discourse, the strategic graduation model towards smart port development will be showcased, which represents an advancement of the DRIP in the form of a digital maturity model for ports (cf. Article III). Hence, in answer to RQ2, the results in the following sub-chapters will show that both models – the DRIP and the strategic graduation model towards smart port development – jointly enable the assessment of the digital performance of ports and strategically safeguard their sustainable digital transformation. Consequently, a strategic approach or roadmap, respectively, is provided for the digital transformation of ports, which identifies the strategic direction and necessary actions to take towards smart port development, which, in turn, will contribute sustainable to Blue Growth.

3.2.1 Digital Readiness Index for Ports – DRIP

Building upon the identified, analysed and synthesised literature findings related to PPM concepts (incl. PPIs), innovative digital and Industry 4.0 readiness indexes and maturity models, as well as insights from the conducted expert interviews and practical findings gathered within the Connect2SmallPorts project, the developed digital readiness index for ports – DRIP – is presented in Table 3 (Article II).

Table 3. *Digital Auditing Tool for Ports – DRIP*

Dimension	Weight	No.	Indicator (* = PPI)	Scale applied
Management	20%	1	Digitalisation Strategy (incl. Governance, Standards, Cultural Guidelines, Progress Indicators, etc.)	Implementation status: 1) Not existing, 2) Pilot initiatives are planned, 3) In development phase, 4) Formulated and defined, 5) Is in implementation phase, 6) Is implemented
		2	Digital Business Model	
		3	Innovation Cooperation	
		4	Investments in Digitalisation	Share of digital investments (x), proportion of employees with an IT educational background (x): 1) x ≤ 10%, 2) 10% < x ≤ 20%, 3) 20% < x ≤ 30%, 4) 30% < x ≤ 40%, 5) 40% < x ≤ 50%, 6) x > 50%
Human Capital	20%	5	IT Knowledge & Skills (Education)*	
		6	IT Capabilities*	Level of #capabilities, scope of training, adequacy of integrated communications, accuracy of information regarding status of shipment, provision of on-time of information, compatibility of operating system, degree of process adaptability in meeting customer requirements, degree of IT security: 1) Very bad, 2) Bad, 3) Rather bad, 4) Rather good, 5) Good, 6) Very good
		7	IT Training & Education Opportunities*	
Functionality (IT)	25%	8	Integrated Communications Infrastructure*	
		9	Information regarding Status of Shipment*	
		10	On-time of Information*	
		11	Operating System*	
		12	Processes*	
		13	Security	
Technology	30%	14	Smart ERP System	Degree of usage: 1) Technology/System not known, 2) No use case available, 3) Usage not planned, 4) Usage is planned, 5) In specific projects already implemented, 6) Comprehensive usage
		15	Smart WMS System	
		16	Smart PCS System (incl. Electronic SCM System)	
		17	Web-based Communication Platform	
		18	Mobile Data Access for Employees	
		19	Mobile Data Access for Customers	
		20	IoT (incl. Machine-to-Machine-Communication)	
		21	Cloud Computing (SaaS, PaaS, IaaS)	
		22	Localisation Technologies (GPS, RFID, etc.)	
		23	Sensors (Humidity, Temperature, etc.)	
		24	Big Data & Predictive Analytics (e.g. for Maintenance, etc.)	
		25	Blockchain (incl. Smart Contracts)	
		26	Artificial Intelligence (AI)	
		27	Robotics	
		28	Drones (Air, Land, Water)	
		29	Autonomous Solutions (Terminals, Cranes, Vehicles) – CPS (Cyber-Physical Systems)	
		30	Digital Twinning, Augmented & Virtual Reality (incl. Simulation)	
Information	5%	31	Personal Network	Degree of information procurement: 1) Very low, 2) Low, 3) Rather low, 4) Rather high, 5) High, 6) Very high
		32	Printed Media	
		33	Internet	
		34	Social Media Resources	
		35	Fairs	
		36	Conferences	
		37	Associations (e.g. Consultancy, etc.)	
		38	Scientific Institutions	

Source: Articles II & III

The digital auditing tool (DRIP) consists of 5 dimensions and 38 indicators, some representing PPIs. The five dimensions were integrated into the tool, since the digital transformation process is not ensured through the sole integration of novel technologies and solutions. Rather it is the result of the interplay of management measures and employees' knowledge, skills and capabilities, as well as functional and prepared IT processes and systems, with these, according to the literature, enabling technologies. Accordingly, all dimensions intertwine, and, in this way, enable a sustainable digital transformation in ports, which, in turn, requires a holistic auditing of their digital readiness. Additionally, a comprehensive information procurement is important in order to be able to identify appropriate and sustainable measures and investments on the path to becoming a smart port. In the frame of the conceptualisation, and thus the selection and definition of the various indicators, a special focus was given to the distinct characteristics of small and medium-sized ports in the SBSR. For instance, as outlined in sub-chapter 2.3.1, small and medium-sized ports in the region do not focus primarily on container handling (Article II). Hence, in answer to the first part of RQ2, it can be stated that the developed DRIP, which is the first of its kind, enables the assessment of the digital performance of ports, regardless of their size and cargo preference (Article II).

3.2.2 Smart Port Maturity Model

In the further research discourse of the doctoral research project, the DRIP was applied in five selected ports: Valencia (ES), Klaipeda (LT), Karlskrona (SE), Wismar and Stralsund (DE), in the course of benchmarking. In accordance with the DRIP presented in Table 3, the evaluation in Table 4 was carried out (Article III). According to Tables 3 and 4, the PPI "IT Capabilities" represents the single indicator in the DRIP model, which was further differentiated into seven sub-indicators ("IT infrastructure", "Automation technology", "Data analytics", "Data security/Communications security", "Development of/Application of assistance systems", "Collaboration software" and "Non-technical skills, such as systems thinking and process understanding"), which underlines its great importance and thus the necessity of raising awareness around it among ports. The detailed results concerning the PPI "IT Capabilities" are shown in Table 5 (Article III).

Moreover, building upon the maturity models from Gill and VanBoskirk (2016) and Gardeitchik et al. (2017), the smart port value creation model from Deloitte (2017), based on Porter's Value Chain Analysis (Porter, 1985), the findings from the conducted expert interviews with top-level managers from the five selected ports (Valencia, Klaipeda, Karlskrona, Wismar and Stralsund), as well as the results from the performed benchmarking, the strategic graduation model towards smart port development was conceptualised, which is presented in Table 6 (Article III). According to Table 6, the typical characteristics and related current strategic positioning, as well as the concrete strategic recommendations, towards smart port development that apply for each port classification (i.e. "Analog port", "Monitor port", "Adopter port", "Developer port" and "Smart port"), dependent on the achieved score based on the DRIP assessment, become apparent. In other words, building upon the indexing via the DRIP and thus the detection of digital performance, the respective current strategic positioning according to each port classification can be derived. Through this, the corresponding strategic recommendations, in accordance to the reached port classification, for a sustainable development towards a smart port can be deduced (Article III). By taking into account the strategic graduation matrix towards smart port development (Table 6), it can be stated that the digital readiness index for ports (DRIP) was refined by a component of the digital maturity model (Article III). Accordingly, and in answer to RQ2, through the conceptualised innovative digital maturity model for ports (Tables 3 & 6), it is possible (1) to assess the digital performance and readiness of ports, (2) to pinpoint the current strategic positioning of ports in the digitalisation context, (3) to categorise ports according their digital maturity status, and (4) to derive the respective strategic direction for a sustainable development towards smart ports (i.e. digital transformation in ports) (Article III). Through this, the sustainable digital transformation of ports is clearly detectable by the defined strategic recommendations in line with each digital port class.

Table 4. *DRIP Assessment*

Dimension	Weight	Indicator (* = PPI)	Valencia	Klaipeda	Karlskrona	Wismar	Stralsund
Management	20%	Digitalisation Strategy	6	6	1	3	2
		Digital Business Model	6	6	2	2	2
		Innovation Cooperation	6	5	2	2	2
		Investments in Digitalisation	4	5	1	2	2
Human Capital	20%	IT Knowledge & Skills*	5	5	2	1	2
		IT Capabilities*	4.7	4.3	3.3	3.7	5.0
		IT Training & Education Opportunities*	5	4	4	4	5
Functionality (IT)	25%	Integrated Communications Infrastructure*	6	5	3	3	5
		Information regarding Status of Shipment*	6	5	3	4	5
		On-time of Information*	5	5	3	4	6
		Operating System*	5	4	4	5	5
		Processes*	5	6	3	4	4
		Security	6	4	4	4	5
Technology	30%	Smart ERP System	5	5	3	5	4
		Smart WMS System	5	5	3	5	4
		Smart PCS System	6	6	4	5	3
		Web-based Communication Platform	6	6	5	5	3
		Mobile Data Access for Employees	6	6	5	5	4
		Mobile Data Access for Customers	6	5	4	5	3
		IoT (incl. M2M-Communication)	5	5	4	4	3
		Cloud Computing	5	4	4	5	3
		Localisation Technologies	5	6	4	4	4
		Sensors	6	5	3	4	4
		Big Data & Predictive Analytics	5	4	3	3	4
		Blockchain	4	4	4	4	3
		Artificial Intelligence	4	4	4	4	3
		Robotics	4	5	3	4	3
		Drones	4	4	4	4	4
		Autonomous Solutions – CPS	4	5	3	4	3
		Digital Twinning, Augmented & Virtual Reality	4	4	4	4	3
Information	5%	Personal Network	4	4	4	4	5
		Printed Media	5	5	5	3	5
		Internet	6	5	5	4	6
		Social Media Resources	6	4	5	3	4
		Fairs	5	4	3	3	6
		Conferences	5	4	4	4	6
		Associations	5	4	4	3	4
		Scientific Institutions	5	4	3	4	5
Results per Dimension – arithmetic mean (without weighting factors)		Management	5.5	5.5	1.5	2.3	2.0
		Human Capital	4.9	4.4	3.1	2.9	4.0
		Functionality (IT)	5.5	4.8	3.3	4.0	5.0
		Technology	4.9	4.9	3.8	4.4	3.4
		Information	5.1	4.3	4.1	3.5	5.1
DRIP Score			**5.2**	**4.9**	**3.1**	**3.5**	**3.7**

Source: Article III

Lastly, through the benchmarking results (cf. Article III & Table 4), it became apparent that all investigated ports exhibit low digital readiness in relation to some digital technologies and solutions: (1) Big Data & Predictive Analytics, (2) Blockchain & Smart Contracts, (3) AI, (4) Robotics, (5) Autonomous Solutions – CPS, and (6) Digital Twinning, Augmented & Virtual Reality (incl. Simulation). Thus, it can be stated that ports in the frame of their digital transformation struggle within these six fields. Hence, research activities should aim to investigate and propose suitable use cases, since these digital technologies have not or have hardly been implemented and used in ports (Article III).

Table 5. *IT Capability Assessment*

No.	Sub-Indicator	Valencia	Klaipeda	Karlskrona	Wismar	Stralsund
6.1	IT infrastructure	4	5	4	5	5
6.2	Automation technology	4	4	3	2	5
6.3	Data analytics	5	5	3	2	6
6.4	Data security/communications security	5	4	4	5	5
6.5	Development of/application of assistance systems	6	4	3	3	4
6.6	Collaboration software	5	4	3	5	5
6.7	Non-technical skills, such as systems thinking and process understanding	4	4	3	4	5
IT Capabilities (arithmetic mean)		4.7	4.3	3.3	3.7	5.0

Source: Article III

Table 6. *Strategic Graduation Model towards Smart Port Development*

Port classification	Characteristics	Strategy description	DRIP Score
Smart port	The port is completely connected via a communications network and fully integrated with its environment (i.e. all stakeholders of the industry) as well as other ports and logistics actors around the globe. Scheduling of the various transport modes is optimised and real-time cargo tracking with all relevant players involved is enabled.	Merge the physical and digital worlds. Ensure steady improvement by continuous development of sustainable and innovative business cases.	5.5 ≤ x ≤ 6.0
Developer port	The port and the hinterland players are connected through one single digital environment, and 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 port targets continuous improvement.	Usage of digitalisation to create competitive advantage and maintain this competitive advantage by targeting sustainable integration and ongoing enhancements. New businesses should be generated and ecosystem partnerships must expand.	4.5 ≤ x < 5.5
Adopter port	The port and immediately involved organisations (regularly: authority, operator, customs, etc.) have started to integrate their (information) systems in order to achieve better communication. Hence, a small, single digital environment will be created, and several advantages, such as better coordination and reduction of waiting times for all means of transportation, can be achieved. The environment is perceived.	Prioritisation of customer relationships depending on own processes and service structure. Strategic decisions should be driven by analytics. Act on environmental changes and consider them in decision-making process. Overall new business opportunities should be identifiable.	3.5 ≤ x < 4.5
Monitor port	Individual automations in the port might emerge. Port authority, operator and related organisations in the near proximity of the port maintain their own processes and databases, as well as have started to digitalise them individually. Accordingly, information and relevant data is captured across specific nodes. The port environment is monitored. Regarding the customers, a statistics-driven policy is in place.	Focus on and improve adaptive capacities. Especially skills and knowledge of employees on all hierarchical levels should be enhanced, whereby an outsourcing strategy for digital expertise represents a suitable alternative. Try to change observer role (slightly) to a more pro-active role.	2.5 ≤ x < 3.5
Analog port	Automation does not exist. The port has no or little knowledge about digitalisation and thus does not know how or is not willing to change. Furthermore, the port typically performs the landlord function. Regarding customers, the first-come-first-serve policy is usually applied.	Change attitudes by increasing awareness of the benefits and added value that comes from sustainable digital development (i.e. digital transformation). Start sensing and shaping.	1.0 ≤ x < 2.5

Source: Article III

3.3 Blockchain and Smart Contracts for Smart Supply and Value Chains

From the benchmarking results, it was possible to deduce that, in terms of their digital transformation, ports show a low digital readiness, among other things, in terms of some digital technologies and solutions. One of the identified critical technologies is Blockchain (cf. sub-chapter 3.2). As described in sub-chapter 1.4, Blockchain technology has special properties that represent key advantages compared to other information technologies. Bearing this in mind, as well as the fact that the potential Blockchain implementation in ports has not been examined in scientific research until now (Koh et al., 2020); although the number of academic studies on Blockchain applications in supply chains has grown considerably since 2017 (Müßigmann et al., 2020), there is still an urgent need to close the identified research gap (cf. sub-chapter 1.4). For these reasons, as well as the lack of implemented use cases according to the insights from benchmarking and thus ports' concrete demand for this technology (cf. sub-chapter 3.2.2), the particular research focus in the following sections is on Blockchain and Smart Contracts.

In response to this, three case studies were developed in Articles IV and V, which, so far, have not been not researched within the scientific literature. Hence, in answer to RQ3, these cases exemplify the advantages in the form of efficiency increases that arise for ports from the sustainable implementation of Blockchain Smart Contracting systems in the internal port processes, in the port environment and in the frame of an innovative business model. At the same time, the use cases jointly show how entrepreneurial collaboration in maritime supply and value chains can be improved through the usage of Blockchain and Smart Contracts and, thus, how especially small and medium-sized ports can become better enabled to integrate themselves into smart supply and value chains. Correspondingly, in the following sub-chapters, the main findings are showcased concerning the investigated charter-party contracting process (i.e. macro-logistics level – port environment), cargo import case in a medium-sized port (i.e. micro logistics level – immediate port sector), and the developed LBG MEC business model for regional ports.

3.3.1 Charter-Party Contract

In Article IV, the charter-party contracting process within a single voyager in the break-bulk market was examined. As a first step, the current situation in the freight market was worked out in order to exemplify the traditional process flow. This was achieved by dividing the overall charter-party contracting process into four phases: (1) pre-fixture, (2) fixture, (3) post-fixture loading, and (4) post-fixture discharging. Each of these phases was analysed in-depth by investigating the role and actions of the involved parties. According to the study in Article IV, the cargo, information and financial flow, on the basis of the current situation in the freight market, can be outlined, as in Figure 5. In a second step, the integration of a Blockchain-based Smart Contracting system and the effects in each process phase were thoroughly discussed, which culminated in an optimised process flow plus the exposition of further benefits that arise from an appropriate technology implementation (Article IV).

The advantages that arise from a Blockchain Smart Contracting system integration in a virtual marketplace, such as OpenSea.Pro, are numerous. However, among all the identified benefits (cf. Article IV), the potential exclusion of the shipbroker can have especially far-reaching positive impacts on maritime supply chains. More precisely, a Blockchain Smart Contracting system can be implemented for the elaboration and enforcement of charter-party contracts, with the effect that the shipbroker becomes superfluous. Hence, such a smart charter-party contracting system reduces the layers of intermediaries in maritime supply chains, since the direct connection of the charterer and ship-owner can be achieved. Enabled through the Smart Contract application on a web-based marketplace, matches can be more quickly identified through the automatically conducted reconciliation of ship-owners' indicated service supply, including the period of availability and the charterers' displayed time-bound service demand, which assists in concluding charter party contracts, while their subsequent processing and execution becomes automated as well. Through this, the information flow is shortened, which additionally saves time. Furthermore, trust, which is traditionally created through the presence of the shipbroker(s), is compensated for by the decentralised nature and inherent high data security characteristics as well as further benefits of the Blockchain and Smart Contract technology (cf. Article IV).

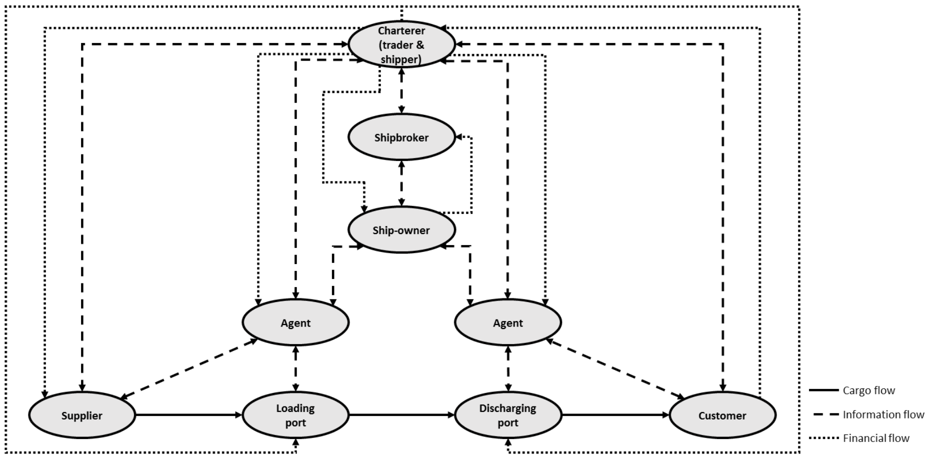

Figure 5. Current Situation in the Freight Market
Source: Philipp et al., 2019a

Moreover, through the exclusion of the shipbroker, cost savings arise that have potential spill-over effects. As a direct outcome, the brokerage fee or commission is saved by the ship-owner. Depending on whether a voyage charter or a time charter is achieved, the shipbroker receives a commission on the gross freight or hire price for the ship. The brokerage fee is also dependent on further aspects, e.g. cargo type, kind of ship, negotiations and agreements with the ship-owner, etc. However, within voyage charters, the commission commonly ranges between 1 and 5%. In contrast, in the case of time charters, the brokerage fee usually amounts to 2.5% of the hire price. Since the ship-owner has to pay the shipbroker, regardless of whether the charterer previously appointed a shipbroker, this results in direct cost savings for the ship-owner. Through the elimination of the brokerage fee, the ship-owner is enabled to lower the charter rate, which consequently is beneficial for the charterer. Furthermore, this can also result in the willingness to pay more for loading and discharging at the ports, as well as wharfage and port dues, etc. Thus, the absence of the brokerage fee may also have positive effects on a monetary basis for all process participants. Hence, the exclusion of the shipbrokers adds value to all stakeholders along maritime supply chains. Especially for smaller and entrepreneurial actors, this enhances competitiveness, improves efficiency and facilitates participation, through the enabling adoption of this innovative technology due to the arising spill-over effects. (Article IV).

3.3.2 Cargo Import

The integration of Blockchain technology in port logistics processes has the potential to enable among other things the transition from a paper-documented process management to a digitalised and more secured one, by validating and storing each action or transaction, respectively, in the chain of blocks. To demonstrate the benefits that arise from a Blockchain and Smart Contract implementation in the immediate port sector, the adoption of this innovative technology was exemplified within a case study in the medium-sized seaport of Wismar in Germany, which was presented in the further discourse in Article IV. Wismar's port logistics for energy sources such as wood pellets and wood chips represents an important link in the biomass value chain, whereby the seaport is active in both the import and export of the related raw material, which, at the same time, classifies its leading role in the Baltic Sea. Hence, especially the local timber cluster in near proximity to the port and in the adjusted hinterland plays an important role for the seaport; and *vice versa* the port for the local and regional industry. Since for the seaport and the local timber cluster, the import of raw materials – in particular wood logs – from Scandinavia has a high relevance, this recurring cargo import has been analysed in more detail (Article IV).

The cargo import may involve directly or indirectly many different actors comprising intermediaries, such as port agents, shipbrokers and freight forwarders; ship-pilots; tug masters; inshore pilots; port office and/or authority; terminal/port operators; customs; harbour police; ship-owners and/or shipping lines; companies of different transportation modes; insurance companies; banks; customers or cargo-receiving companies; and other supply chain stakeholders. When a vessel moors at the quay in the seaport, all cargo-related files are usually processed or transmitted, respectively, by the port agent. Thereby, the necessary information that is traditionally recorded on physical paper documents (e.g. bill of lading, etc.) is forwarded to the comprehensive INPLAN Port Management System at the Wismar seaport. INPLAN eases the forwarding of relevant data and information to the majority of process-involved stakeholders and thus supports the handling of the respective cargo. Nevertheless, the two main pitfalls are that firstly, the entire operation process flow of the port is not covered and monitored by the system, and secondly, not all relevant internal and especially external stakeholders are directly connected to the system. Consequently, the communication between all involved parties is not optimally ensured and, in many cases, it is inefficient through outdated channels (e.g. telephone or physical paper documentation and forwarding), leading to the presence of fragmented databases, slowdowns of the process flows and an underperforming supply chain (Prause, 2014b) (Article IV).

In the course of a conducted analysis of potentials of a possible permissioned Blockchain implementation, it was derived that the technology fosters the data exchange between the involved parties in the entire process. This is because the implementation of Blockchain and Smart Contract solutions breaks down the central control and information system architecture. All relevant cargo-related information can be stored on the Blockchain once the corresponding participants have approved the uploaded documentation or data, respectively. At the same time, the use of the Blockchain guarantees access to the data and information at all times and in real-time for all participants – including external stakeholders – if permission is granted. Besides the data reading permission, specific parties can be additionally equipped with a data writing permission. Overall, the Blockchain implementation has the potential to streamline, in particular, the information flow and to decrease transaction costs and thus the total transportation costs. Furthermore, the implementation of IoT sensors with a direct linkage to the Blockchain may provide the distributed and decentralised network with real-time data about the cargo condition and location at all times. For instance, nowadays, wood logs especially are already secured against theft after deforestation by GPS trackers. Thanks to a GPS tracker, which is located in the wood log, it is always possible to trace its location. Through this, the cargo flow can be optimised due to the provision of additional cargo-related information that supports cargo-handling activities, while additional sensor integrations (e.g. humidity sensors) immediately indicate the need for action in the case of cargo quality impairment (Article IV).

Due to the implementation of a Blockchain Smart Contracting system, plus taking into account the research findings from the investigated charter-party contracting process, a reduction of administration costs of about 4 to 5% of the total costs was predicted for the seaport, whereas shorter process times would generate additional cost savings. Moreover, the possible exclusion of further information intermediaries (e.g. port agents) and thus lower manual works, less needed personnel for quality control checks, ensured cargo tracking and tracing, as well as earlier countermeasures in the case of detected cargo quality impairments in real-time through integrated IoT devices, sensors and trackers in the operative port processes can generate additional direct cost savings. Likewise through this case, it was deduced that for smaller and entrepreneurial actors, the implementation of Blockchain and Smart Contracts fosters competiveness, increases efficiency and facilitates participation, whereas the adoption of this novel technology becomes enabled as well through lower total supply chain costs (Article IV).

3.3.3 LBG MEC Business Model

In Article V, the study targeted the development of an innovative business model for regional ports, in which a special focus was placed on LBG in order to promote the supply and utilisation of biofuels and renewable energy. Besides, the research showed that Blockchain and Smart Contracts foster the implementation of the business model and optimisation of value chain operations. In a supplementary step, a comparative analysis with ULSFO was carried out. For this purpose, a case study approach was used to exemplify the operating principles and benefits of the business model. The case study referred to the medium-sized seaport Karlskrona in Sweden and the RoPax ferries from Stena Line that travel back and forth to the Gdynia seaport in Poland (i.e. SECA in the BSR) (Article V). Hence, building upon the field-to-ferry-concept from the GoLNG project and the MEC model from Olaniyi et al. (2019, 2018a, 2017) – which is based on the Energy Service Contract (ESC) approach – in the course of the new business model, the port will henceforward provide LBG to ship-owners' vessels (i.e. energy/fuel supplier role) and will become responsible for arranging the retrofit of the vessel towards a dual fuel engine that is also able to combust LBG, as well as the subsequent maintenance (i.e. energy/fuel service role). The so-called LBG MEC business model was elaborated by applying the Business Model Canvas from Osterwalder and Pigneur (2009). Thereby, two potential cases were investigated: (1) the port focuses on the organisation of the downstream LBG value chain, as roughly described above, and (2) the port also considers horizontal integration in the upstream LBG value chain. Initially, in order to launch the LBG MEC business model, the port focalises on the downstream LBG value chain, i.e. primarily on the ship-owner as the main end-user (Article V). The LBG MEC business model is presented in Figure 6.

According to the findings, LBG distribution and inventory in the port can be monitored automatically through the implementation of Blockchain and Smart Contracts. For instance, regarding fuel supply for the ships, the IoT sensor applications of the tank on board can monitor and send the fuel consumption and need in real-time to the port or terminal. The delivery of LBG from port bunker to the ship's tank can be monitored by the Blockchain (i.e. controlled distribution). Hence, when the ship is in the port and needs fuelling, the back and forth sending of information and physical documents, as well as the creation of respective copies for the overall process, are no longer needed. Thus, the integration of a Blockchain Smart Contracting system has the potential to foster the establishment of full- or semi-automated LBG bunkering and fuelling operations in the port (Henesey & Philipp, 2019). Moreover, Blockchain and Smart Contracts enable automatic forecast calculations and the triggering of LBG repeat orders, which avoids shortages of LBG supply in the port.

Bearing this latter aspect in mind and transferring it into the context of a potential enlarged case, in which either all actors in the value chain participate in the same Blockchain (i.e. joint digital infrastructure) or the port is possibly developing or integrating into the local or regional LBG value chain, a Blockchain Smart Contracting system is able to optimise the management of the entire chain. This is because, through Blockchain and Smart Contract applications, the upstream LBG value chain nodes and entities can receive real-time information and predictive data about the current, and expected, future consumption or demand of the downstream LBG value chain, including the end-users. Accordingly, with a Blockchain Smart Contracting system, value chain management becomes smarter and thus more efficient, since resource-optimised production along the whole chain is ensured through automatically generated real-time and forecast data.

Moreover, this includes the possibility that Smart Contracts automatically conduct the financial calculations and the related generation of billings and resulting payments, e.g. for the farmers who produced the biomass for the biogas plant, as well as for the intermediate product, fuel and energy supply of downstream stages of the value chain or end-users. This is achieved through the underlying Blockchain, in which the needed input data is available through IoT applications and integrated market data, as well as the Smart Contracts, which include all the respective rates, prices, terms, etc. along the chain. The same applies for the planned or spontaneously induced inspections and maintenance of tangible key resources, and, if a contractual relationship with an end-user (e.g. ship-owner) prematurely ends, since the respective Smart Contract application is able to automatically perform the needed calculations (e.g. residual value and thus the necessary one-time compensation) and subsequent generation of the billing. Hence, all occurring financial calculations, billings and transactions along the LBG value chain can be automatically performed and triggered if all respective pre-defined conditions are fulfilled and thus, all relevant data and information is available in the chain of blocks through uploaded, secured and shared files. As a result, objections by the involved parties can be limited due to the decentralised nature and inherent high data security characteristics of the Blockchain and Smart Contract technology. Accordingly, this procedure guarantees a trustful and fair approach for automated concluding calculations as well as monetary transactions, which additionally decreases costs due to shortened process time and lower manual labour. Therefore, it can be stated on the basis of all three investigated cases that Blockchain and Smart Contracts are able to make a significant contribution in the pursuit of the enhanced facilitation of material, information and financial flows in maritime supply and value chains.

	Value propositions	Customer segments	Customer relationships	Key partnerships	Key activities	Key resources	Channels	Revenue streams & cost structure	
Kick starting	Superordinate value proposition is the significant contribution to the reduction of emissions & the sustainable switch from fossil to bio-fuel or renewable energy, respectively	Main costumers are ship-owners, shipping companies or ship-operators, who have to show compliance to IMO emission regulations & fear retrofits due to high investments, risks or uncertainties	Port & ship-owner become close partners with a strong relationship that will be contractually fixed; all-round carefree package: LBG supply, dual fuel engine & regular engine maintenance, etc.	• LBG bunker trader (fuel broker) or biogas liquefaction company (only for launching the business model) • Shipyard or maintenance company • Investment bank • Insurance company	• LBG supply & additional services like arrangement of engine retrofit & maintenance → planned & arranged individually for each vessel • Staff training • Ensuring secured data information exchange	• LBG • Fueling systems for pumping LBG into vessel's tank • Dual fuel engine, LBG ship tank & pumping system, etc. • LBG experts & service personnel • Blockchain, IoT sensors	• LBG supply via ship-to-ship (STS), truck-to-ship (TTS), pipeline-to-ship (PTS) transfer, or portable tanks, whereas LBG distribution & inventory automatically monitored by Blockchain + Smart Contracts • The maritime energy contracting process includes the three phases (1) pre-fixture, (2) fixture & (3) post-fixture: (1) Smart Contract automatically conducts initial calculations for the project (incl. ø needed regular LBG quantity, maintenance & inspection schedule & ø costs, LBG supply price) & some kind of pre-contract according to provided data from ship-owner, shipyard & stored market data in the Blockchain (2) Negotiation process & fixing of contract (via digital signature) automated by Blockchain Smart Contracting setup lifecycle (3) Embraces mainly monitoring tasks that refer to fueling of ship & maintenance: smart maintenance is enabled by IoT sensors of engine; further IoT sensors of ship tank monitor & send fuel consumption in real-time to port; Blockchain & Smart Contract enable automatic forecasts & triggering of repeat orders	ULSFO price = 577.72 €/MT Cost savings for Stena Line = 48.48 €/MT LBG MEC price for Stena Line = 529.24 €/MT Adjustment (gross profit Karlskrona) = 35.76 €/MT Asset costs = 35.38 €/MT LBG baseline price = 458.10 €/MT	Downstream LBG value chain
Maturity stage	Port, further potential customers & other stakeholders in the local or regional costal area benefit from fewer emissions → adds value to the society, but also to the environment in general	Potential to extend the business model to other transport modalities, the industrial sector, gas grid operator(s) in near proximity to the port	If clientele will be enlarged, this will be achieved always on a contractual basis, whereas the inter-dependencies & scope of services define the business relationship	• Farmers • Suppliers of biogas plant, upgrading & liquefaction technologies – needed for construction as well as maintenance → Investment for creation of LBG value chain ≈ 10M€, whereas co-financed by CEF (TEN-T)	Initially, identification of suitable funding schemes; plus generation of public awareness (integrative communica-tion process in the region) & political support for legal permissions	• Facilities for production & bunkering of biogas & LBG, i.e. ≈ entire LBG value chain • Staffs' skills along LBG value chain • If clientele is enlarged, new or intermediate products incl. supply facilities	• Through Blockchain & Smart Contract applications, the upstream LBG value chain nodes receive real-time information & predictive data about the current as well as expected future consumption or demand of the downstream LBG value chain – including the end users → resource-optimised production along the whole value chain & thus, avoidance of over & under capacities & shortages • Smart Contracts automatically conduct the financial calculations & related generation of billings & resulting payments/transactions, which is achieved through the underlying Blockchain, in which the needed input data is available through IoT applications, integrated market data & previously fixed digital contracts along the value chain → objections limited, as this is a trustful & fair approach for automated concluding calculations & transactions • Private permissioned Blockchain is recommended → Blockchain & Smart Contracts perfect material, information & financial flows in supply & value chains & ensure disintermediation, which decreases transaction & enforcement costs		Upstream LBG value chain

Figure 6. LBG Maritime Energy Contracting Business Model for Regional Seaports
Source: Compiled by author

4 Discussion

The results that refer to RQ1 revealed that the future Blue Growth potential of the Maritime Economy in the SBSR can only be evaluated as moderate. Furthermore, it became obvious that the future growth potential is not homogeneous among the investigated nine Blue Economy sectors in the SBSR. Particularly, the sectors Aquaculture, Blue Bioeconomy & Biotechnology, Fishery, Seabed Mining, Offshore Oil & Gas, and Maritime Transport show (rather) low future growth potential, which can be traced back mainly to the low growth prospects of international markets, i.e. primarily outside Europe.

However, the rationale for the results obtained may vary widely for each sector. In addition to the generally low demand in the international markets (i.e. Africa, Asia, Australia, North America and South America) for products and services from the SBSR, in the following some of the major reasons are discussed within the context of the European market: As carved out within in sub-chapter 1.1, EU citizens consume Aquaculture and Fishery products more than twice as much as is produced inside the EU, which suggests that the majority of the production is distributed in the EU, and only a fraction is declared for overseas markets, a situation which is unlikely to change significantly in the foreseeable future based on the results obtained. Another reason for this circumstance can be seen in the strict EU regulations concerning fish catch quotas and the stagnation in the expansion of the primary sector Aquaculture (EC, 2020). Similarities exist with regard to the Seabed Mining sector and thus the demand for marine aggregates dissolved in seawater (i.e. sand and gravel). The steadily increasing demand in the EU for construction materials to maintain and develop transport, energy and water infrastructures and built environments that society relies upon, are responsible that the bulk of such materials produced within the EU also stay in the respective domestic markets (Pascual & Jones, 2018). Further drivers in the EU include the replenishment of beaches and the improvement of coastal defences (ibid.). Blue Bioeconomy & Biotechnology is an emerging sector that is still not widely commercially deployed (EC, 2020), which explains the expected low future growth potential in international markets in the forecast horizon 2019–2013. Therefore, no comparatively high growth rates can be expected until the associated products and services have reached sufficient market maturity, which, according to the results, is unlikely to happen to a significant extent until 2023. Oil and gas are still by far the most significant energy sources for the European economy and society; hence, exports are much lower than imports. In 2018 in the EU, the need for oil and petroleum products amounted to 547.3 Mtoe, of which 94.6% were imported, followed by natural gas with 324.6 Mtoe, of which 83.2% came from imports (Eurostat, 2020d). Currently, highly discussed projects, such as “Nord Stream 2”, underline that this strong dependency will most likely continue to exist in the next decades. On the other hand, generally the oil and gas production of the European member states is relatively small in comparison to the USA, Saudi Arabia, Russia, etc., which control much larger oil and gas reservoirs (Eia, 2020). At large, these aspects elucidate the general low future growth potential of firms from the SBSR, especially in other international markets than Europe. The results of the Maritime Transport sector have to be considered in a more differentiated way, since the CAGRs of the European and Asian markets are moderate, but in case of the other international markets indicate a rather low future growth. Nevertheless, compared to the other blue industries with generally dimmed growth prospects (i.e. Aquaculture, Blue Bioeconomy & Biotechnology, Fishery, Seabed Mining, and Offshore Oil & Gas) in international markets, the respective results of the Maritime Transport sector are much more auspicious (with the exception of the projected CAGR in the case of the Blue Bioeconomy and Biotechnology sector in the North American market), although the overall future growth potential has to be evaluated as rather low. However, the results in relation to the Maritime Transport sector in the SBSR suggest that short-sea shipping will grow faster than deep-sea shipping.

The determined CAGRs on a turnover basis in Appendix 2, which were mooted in sub-chapter 1.1, refer to data on the NUTS 0 level and thus exceed the factual geographical catchment area of the SBSR. Therefore, direct comparisons with the determined CAGRs that refer to the forecast horizon 2019 to 2023 are not allowed. Nevertheless, on a general basis, it can be abstracted that the future growth potential of the Blue Economy sectors in the SBSR is lower than the recorded growth between 2009 and 2018 concerning the adjacent EU countries of the SBSR. An exception is the Offshore Oil & Gas sector in the SBSR, which has a slightly positive future growth potential but a negative growth development in the time horizon 2009 to 2018 concerning the adjacent EU countries of the SBSR. Thus, although a lower future growth potential in the mature sectors – Aquaculture, Coastal Tourism, Fishery, Seabed Mining, Shipbuilding & Repair, and Maritime Transport – was somehow expectable in comparison to the emerging or young sectors of Blue Bioeconomy & Biotechnology and Marine Renewable Energy, the forecast results are significantly lower than the figures that map the past development. This can be traced back, among other things, to the fact that the study in Article I followed a rather pessimistic perspective, since turnover growth rates over 20% were considered as outliers and therefore were excluded from the analysis. This means that the gained results are closer to more realistic market conditions, which relatively unexpectedly also to a certain extend stays abreast the occurred COVID-19 pandemic and the related economic impacts – apart from the fact that the intensity of the economic effects will differ naturally among the sectors.

However, if this imbalance – i.e. the turnover growth in domestic markets increases more rapidly than in international markets – continues and becomes even greater, which is what the results of the determined CAGRs suggest (cf. sub-chapter 3.1.1 and Article I), it can be implied that the degree of internationalisation in companies from the sectors Aquaculture, Blue Bioeconomy & Biotechnology, Fishery, Seabed Mining, Offshore Oil & Gas, and Maritime Transport will not increase. In general, this indicates among other things that collaborative activities in case of firms that belong to these six identified critical sectors are not sufficiently, and that they tend to work rather in isolation, which also implies a lack of interconnectedness. Thus, according to the cluster theory and innovation network aspects, these internal characteristics may also explain the low future growth potential of the Maritime Economy in the SBSR. By focusing on networking and regional innovation aspects, Goddard developed the idea of regional knowledge or innovation networks. In the globalised knowledge society, the competitiveness and prosperity of regions depend on the strengths and innovation power of the local economy; in other words, success in the future will be for those companies and urban or rural areas that are able reach global standards and join global networks and markets (Goddard, 1997). Hence, the competitiveness of an enterprise depends on skilled employees and innovative products or services (Goddard, 1997, 2000). Therefore, the access to knowledge, skills and innovation at the local level has become as important as the infrastructure (Philipp et al., 2019b; Prause, 2015b). Accordingly, cooperation between companies, and with regional R&D institutions and stakeholders, forms the nucleus for the creation of regional innovation networks, which becomes a key and driving force for the development of the local economy (Goddard, 2000). Consequently, regional development is an innovation process that is heavily dependent on individuals' interactions within a system or geographical area (Philipp et al., 2019b; Prause, 2015b). *Vice versa*, these interactions are the wellspring for innovations and knowledge generation and thus function as the driver for the economic growth and sustainable development of regions (ibid.). Correspondingly, the structures and types of interactions between knowledge providers, distributors and users determine sustainable innovations (Goddard, 1997). Hence, collaborative innovation activities with other companies, research institutions and stakeholders are key factors in the ability to successfully compete in the global economy, in which cluster and network initiatives are fundamental. Accordingly, it can be suggested that policies should seek to further promote network activities within the blue sector in the SBSR (i.e. especially increase integration of the identified low performance sectors in the course of cross-border network activities in the region), as more interactions will result in more entrepreneurial business creations, knowledge and innovation generation, which, in turn, will lead to productivity increases, higher employment and new jobs (cf. Article I; Goddard, 1997; Philipp et al., 2019b; Prause, 2015b). In the long term, such policy measures and network interactions should be targeted towards the development of a maritime cluster, due to the prevalent maritime spatial aspect in the SBSR, since this has the potential to ensure the achievement of competitive advantages on micro and macro level. Through this, the maritime enterprises in the SBSR will more easily be able to fulfil global standards and develop competitive operational models, which will enable them to compete on the global arena and thus counteract or prevent the low future growth potential, as detected by the results of the RQ1 investigation.

Furthermore, the findings concerning RQ1 showed that digitalisation is expected to have the greatest positive impact on Blue Growth in the SBSR, in comparison to the TEN-T regulations or the IMO sulphur directives, namely the SECA Regulations and the Global Sulphur Cap. On the one hand, this supports the key takeaways of the new institutional economics theory, which states that governmental interventions in the form of regulations do not encourage economic growth (Coase, 1998; Eggertsson, 2013). On the other hand, these results are in line with the endogenous growth theory, which maintains that economic growth is primarily the result of internal forces rather than external ones (Romer, 1994, 1986). Accordingly, digitalisation and the related need for digital transformation as an internal force in companies of the maritime industry in the SBSR is expected to have a greater impact on Blue Growth than external forces coming from regulations that do not function as direct investments in human capital – here in the form of the TEN-T regulations and IMO sulphur directives. Nevertheless, both regulations form government-imposed incentives for entrepreneurial activities and technological progress (e.g. in order to comply with the sulphur restrictions) and thus, according to the findings of the doctoral thesis, are expected to have overall a positive, but softer impact on Blue Growth in the SBSR. Therefore, it can be derived that for sustainable Blue Growth in the SBSR, policies as well as investments from the private sector have to target the enhancement of human capital (cf. Lucas, 1988), as this will have a strong effect on the creation of new technology developments and the improvement of productivity on the basis of a stimuli for product and process innovations. Thereby, especially the knowledge-based sectors, such as telecommunications, IT and ICT, play an essential role. Related to this is the encouragement of entrepreneurship as a measure for the generation of innovative business segments and digital innovations, which additionally leads to a higher employment rate and the creation of new jobs. Hence, digital innovations and digital transformation processes, which can only be encouraged through the sufficient skills, capabilities and knowledge of employees (i.e. human capital), are direct drivers of Blue Growth. Conversely, it can be noted that the digital transformation is not driven, if investments in human capital and innovations are neglected, which render them as critical success factors. Thus, particularly investments from the private sector in R&D form the essential driver for technological progress (Romer, 1987, 1990) and thus the digital transformation. Consequently, it can be stated that technological change and thus the digital transformation process, as well as the related efforts in Maritime Economy firms including ports, are grounded especially on private R&D investments that spur innovations and thus have the potential to promote Blue Growth in the SBSR.

By taking a holistic view of the findings on RQ1, further implications can be derived in terms of smart specialization strategies. As regional development is an innovation process that depends on interactions, especially within smart specialisation strategies more interactions between the private sector and regional R&D institutions are necessary to promote economic prosperity in the European regions (Philipp et al., 2019b). Smart specialization (S^3) as a key element in the European regional policy in the framework of the Europe 2020 Strategy, and its Innovation Union initiative (Del Castillo et al., 2011) represents an opportunity for the EU regions to generate wealth and jobs through an entrepreneurial discovery processes. According to Foray et al. (2009) and Foray (2009), the entrepreneurial discovery can be described as a learning process through which the regions pinpoint their R&D and innovation priorities, and building upon this, transform the economic regional structure in order to generate sustainable growth and employment. Consequently, the smart specialization concept is based on the idea that the European regions identify technological and knowledge domains, which eases regional policy makers to establish and launch target-oriented policies for the promotion of innovations in these domains, so that in the long term, competitive advantage is achieved for survival on the global arena (Foray et al., 2009). Since innovative interactions are apparently insufficient in the case of some Maritime Economy sectors in the SBSR, and digitalisation has been identified as the main driver for superior Blue Growth in the region, policy measures should target, among other things, the formulation of matching innovation strategies that facilitate the digital transformation of the maritime sector in the SBSR. Smart specialization becomes necessary as the transformation process itself as well as the related manifold digital technologies and their implementations require actions at a very high level of knowledge. Accordingly, only through the bundling of specialist knowledge in particular areas or even niches can operations on the required know-how level be enabled and thus the aspired superior development realised. Hence, the crucial specialisation and prioritisation of innovative technological R&D intensive core fields can function as the engine for the formation of high-calibre professional knowledge as well as the implementation of high technology standards. Through this, competitive advantage can be achieved on a company and regional level, which enables growth and prosperity. To reach a smart symbiosis between the aspired digital transformation and smart specialization strategies, however, comprehensive expertise is needed concerning the different enabling technologies of Industry 4.0 (Kudrina et al., 2019). This calls for additional investigations to identify critical technology areas with a high potential to promote sustainable development and economic growth and in which Maritime Economy firms in the SBSR show deficits or implementation problems.

The research results for RQ2 appeared first in form of the conceptualised DRIP model. Subsequently, the conducted benchmarking (Article III) with the seaports Valencia (ES), Klaipeda (LT), Karlskrona (SE), Wismar and Stralsund (DE) uncovered the problems and challenges faced by small and medium-sized ports in their digital transformation. Besides the general low development and application progress concerning the different enabling technologies (an exception is “Drones”), as well as the low performance in terms of the different indicator results that refer to the dimension Functionality (IT) (an exception is the small port Stralsund), the study revealed that especially regarding the Management indicators (i.e. “Digitalisation Strategy”, “Digital Business Model”, “Innovation Cooperation” and “Investments in Digitalisation”) small and medium-sized seaports (Karlskrona – SE, Wismar and Stralsund – DE) are lagging behind in comparison to the investigated core ports (Valencia – ES and Klaipeda – LT). Similar grave backlogs were observable for small and medium-sized seaports concerning the PPIs that belong to the dimension Human Capital, namely: “IT Capabilities” (an exception is the small port of Stralsund) as well as “IT Knowledge & Skills”. Against this, it was noticeable that the small and medium-sized seaports are trying to catch up their information gap and attempting to improve their human capital, since the results pertaining to the PPI “IT Training & Education Opportunities”, as well as all the indicators in the dimension Information, are comparatively high. The findings for RQ2 are in line with theory, as the different theoretical streams which the doctoral thesis builds upon can explain why the larger ports Valencia and Klaipeda are more successful.

The great significance of the indicator “IT Capabilities” in the dimension Human Capital becomes apparent in the light of the resource-based view theory. The integrated enabling technologies that are set out in the corresponding dimension may constitute, under certain conditions, VRIN resources. However, in most cases, the possession and application of a single resource will not yield the aspired advantage (cf. Amit & Schoemaker, 1993; Coates & McDermott, 2002; Leonard-Barton, 1992; Makadok, 2001; Teece et al., 1997; Wade & Hulland, 2004; Wernerfelt, 1984). It is rather the bundling and combination of these different technologies and digital solutions that delivers the desired result. This bundling and combination represents a difficult endeavour that requires comprehensive knowledge about the costs and benefits of the different technologies, and building upon this, expertise regarding the appropriate and reasonable application and adaptation within the immediate port environment for the improvement and transformation of the internal port processes and services. Hence, the digital transformation and the achievement of a competitive advantage strongly depends on the IT capabilities of the enterprise (Chen et al., 2014; Nwankpa & Datta, 2017; Nwankpa & Roumani, 2016; Wade & Hulland, 2004) or port, respectively. Nevertheless, as mentioned indirectly, comprehensive knowledge about the different enabling technologies and solutions is not enough. What is most decisive is the meaningful application in the underlying port processes and services—which is reflected by the dimension Functionality (IT). For this reason, the sub-indicator “Non-technical skills, such as systems thinking and process understanding” was integrated into the concept as well, which extends the scope of classical abilities under the umbrella of IT capabilities. A strong relation may be seen to the indicator “Digitalisation Strategy” in the dimension Management, as this indicator is embedded in the field of strategic management also. Another example is the indicator “Digital Business Model” in the dimension Management, which relates to business model innovation and, in a certain way, to the transaction cost theory, as the digital transformation enables the conversion of traditional business models into digital ones or the creation of new digital or digital-supported business models (Geissdoerfer & Vladimirova, 2018; Ibarra et al., 2018), which, according to the outlined theoretical background, have the potential to achieve higher economic efficiency (cf. sub-chapter 1.5) as well as competitive advantage (Chesbrough, 2010, 2007; Mitchell & Coles, 2003). The indicator "Innovation Cooperation" in the dimension Management refers to the cluster theory and innovation network aspects (Goddard, 1997, 2000), which – transferred into the context of the dissertation – postulate that only those ports will be successful in the globalised economy and in their digital transformation process that enter into and interact within networks or clusters. This latter aspect is underlined by the point in sub-chapter 1.3 that the digital transformation process in ports is targeted to reach the smart port stage, in which ports are optimally connected with their environment and all ports globally with each other through the application of diverse digitalisation technologies (Gardeitchik et al., 2017). Accordingly, it can be argued that the digital transformation is also dependent on the ability of ports to join and interact within clusters or networks. Hence, collaborative innovation activities with other ports and stakeholders represent key success factors. On the other hand, through the progressive digital transformation process, the spatial aspect, which is seen as a crucial driver for the success of clusters, will increasingly lose importance, since the digital technologies and solutions facilitate a smooth communication and knowledge exchange, regardless of geographical distance. Against this, the importance of the indicator "Investments in Digitalisation" in the dimension Management and the PPIs "IT Knowledge & Skills" and "IT Training & Education Opportunities" in the dimension Human Capital becomes apparent against the background of the endogenous growth theory, which maintains that especially investments from the private sector in innovations and human capital deliver the desired push effect for technological progress and thus sustainable development and growth (Lucas, 1988; Romer, 1987, 1990). Lastly, a comprehensive information procurement ensures knowledge generation as well as appropriate decision-making, such that the dimension Information can be regarded as an assisting and overarching bridgework for all other dimensions and indicators and thus in the overall theoretical setting.

Hence, it can be implied that small and medium-sized ports have to take measures to overcome their grave backlogs concerning the DRIP dimensions Management and Human Capital, since without a clear "Digitalisation Strategy", "Innovation Cooperation" activities, "Investments in Digitalisation", the necessary "IT Knowledge & Skills", as well as "IT Capabilities", the digital performance and transformation will not be safeguarded, since these aspects represent the essential and fundamental framework conditions. The Functionality of the IT processes and services can be ensured through an effective and appropriate deployment of the different digital technologies and solutions, both of which can only be efficaciously tackled if the basic conditions – regarding Management and Human Capital – are adequately met.

Furthermore, the research results concerning RQ2 appeared in the form of the conceptualised strategic graduation model towards smart port development, which complements the DRIP model. Together, both models mould the digital maturity model for ports. Building upon this, for both the Valencia and Klaipeda seaports, which can be classified as "Developer ports", it can be strategically suggested to use the achieved high digitalisation degree for the creation of a competitive advantage and to maintain this competitive advantage by targeting the further and broader sustainable integration of the hinterland, and thus to extend the network of stakeholders by exceeding the hinterland. In addition, new businesses and segments should be generated, whereby ecosystem partnerships should expand. Concerning the two German ports (i.e. Stralsund and Wismar), which can be categorised as “Adopter ports”, it is recommended that they prioritise customer relationships depending on their own processes and service structures. Additionally, strategic and other decisions should be driven by analytics, whereby environmental changes must be stronger and more thoroughly taken into account during the decision-making process. Moreover, another strategic objective should be to identify new business opportunities. Regarding the Swedish port Karlskrona, which can be categorised as a “Monitor port”, it can be suggested to focus on and improve its adaptive capacities. Particularly the capabilities and knowledge of the employees at all hierarchical levels should be improved, whereby outsourcing for the acquisition of digital knowledge and expertise represents a suitable alternative strategy in the frame of the overall digitalisation strategy. Furthermore, the Karlskrona port should strive to move from an observer role to a more pro-active one.

The results concerning RQ3 showcased that Blockhchain and Smart Contracts in the port environment (macro-logistics level) and immediate port sector (micro-logistics level) contribute to the reduction of transaction and enforcement costs through disintermediation. Through this, the economic efficiency in ports, in the maritime sector and in supply and value chains can be increased. Consequently, all presented cases showed how Blockchain and Smart Contracts foster entrepreneurial collaboration in cross-organisational business processes that are distinguishing for smart supply and value chains, and, at the same time, highlighted how this technology can enable small and medium-sized ports to integrate better into smart supply and value chains.

Concerning the first investigated case study, the proposed implementation of the Blockchain and Smart Contract technology within a web-based marketplace for the generation of smart charter-party contracts represents a grass-root concept of a digital business model (i.e. business model innovation). The case study showed the potential of Blockchain and Smart Contracts through the possible simplification of the business processes in the freight market, including the preclusion of the shipbrokers. All identified aspects of the optimised process flow reduce costs due to shortened process time and lower manual labour.

The second case study in the seaport of Wismar, which focused on the underlying cargo import case, showcased the potential of the Blockchain and Smart Contract technology through the possible simplification of the port logistics processes. Through the usage of a Blockchain platform for a comprehensive and distributed data and information storing and sharing, Smart Contract applications for the automatised execution of specific actions and transactions, as well as IoT devices, sensors and trackers, the entire cargo flow in the port becomes trackable. Hence, the investigated case study exemplifies an essential step towards a partly or fully automated operational process flow on the road towards smart port development. Thereby, the IoT devices and sensors feed the Smart Contract applications with data, whereby the generated real-time data is stored on the Blockchain and thus visible to all network participants. On the basis of the case study results, it can be further noted that especially the incorporation of tracking systems (e.g. GPS) and sensors encourage the desired development towards a smart port.

The third examined case presented an innovative business model with a special focus on LBG supply and distribution via the port. Against the background of business model innovation, the developed innovative business model does not represent a digital business model. Nevertheless, the investigated case exemplifies how Blockchain and Smart Contracts foster the implementation of the elaborated LBG MEC business model and the optimisation of underlying value chain operations, as well as the emergence of a green transport corridor.

In general, the results concerning RQ3 indicate higher flexibility for relevant data sharing, since Blockchain represents an open platform with low entry costs that is accessible to anyone (if permission is granted or not needed) who shows interest in participation. Accordingly, a common Blockchain platform can replace the historically grown incompatible systems of different internal and external business entities and thus support better integration of all actors in the supply and value chains. The ledger- storing procedure ensures network access at any time and real-time information retrieval for all participants. Hence, physical documents are no longer needed, and each authorised participant is able to sign digitally via a private key, verify data and fetch copies. Within suggested permissioned Blockchains, it becomes feasible to clarify access and alteration rights, as well as proof of personal identification. Besides this, in a permissioned Blockchain, specific information can stay private or can be shared in a filtered form, which represents an additional data security aspect (e.g. for business secrets) but also has the potential to prevent data flooding. Additionally, simultaneous document processing and transparent process tracking is ensured at all times. Through a Blockchain implementation, all information is secured in a decentralised and distributed way that is fraud-resistant, irreversible, steadily verifiable, retraceable and always retrievable. All these characteristics enhance trust within the network and increase efficiency of the process flows, i.e. cargo, financial and information flows. Moreover, Smart Contracts are empowered to automatically generate and distribute important files and documents (e.g. charter-party contract, bill of lading, etc.). Thus, the related auditing process of documents and relevant external data that is provided, among other things, via IoT sensors and trackers can be automated as well through Smart Contract applications. Hence, enabled through the programmed processing of data, concluding calculations and transactions can be automated as well. However, the findings for RQ3 also highlighted that Blockchain and Smart Contracts alone do not deliver the desired results. Only in combination with the IoT, virtual marketplaces, etc. can this technology unfurl its potential power, which can be traced back to the above-mentioned aspect that, in terms of the resource-based view theory, appropriate IT capabilities are required for an effective and efficient bundling of resources or technologies, respectively, for the generation of competitive advantages.

Conclusion

The central goal of this doctoral thesis was to develop a conceptual and processual model that ensures the sustainable digital transformation of small and medium-sized ports in the SBSR, so that they become the main innovation drivers for Blue Growth in the region. The thesis carved out that digital transformation in ports is an intricate endeavour, in which manifold aspects have to be taken into account. Nevertheless, building upon the conducted scientific studies, the research showed as well that digital transformation has to be considered as an entrepreneurial discovery and strategic process that is accompanied by radical technological and organisational changes.

Deeply rooted in the fact that ports are the central hubs and nodes in diverse supply chains, their actions within change management have enormous and far-reaching spill-over effects. Ports are the essential and dominating players in the global transport system, which connotes that innovative changes in ports affect the entire economic environment. Hence, their failure or success has a tremendous and multi-layered impact on the different Blue Economy sectors, as well as on all further linked industries, and thus on the economic growth and prosperity in the corresponding regions. This also implies that the digital transformation in ports requires the comprehensive inclusion of clients and stakeholders, since ports are still service providers.

The conceptualised and processual digital maturity model for ports that embraces the DRIP model, as well as the strategic graduation model towards smart port development, enables to evaluate the digital performance and readiness of ports, to pinpoint the current strategic positioning of ports in the digitalisation context, to categorise ports according their digital maturity status and to derive concrete digital strategic actions. In this way, the roadmap for the digital transformation of ports towards smart port development is clearly identifiable by the defined strategic recommendations according to each digital port classification. Hence, building upon the elaborated digital maturity model, it can be concluded that through the supported sustainable digital transformation and the special focus on specific digital enabling technologies, such as Blockchain and Smart Contract, small and medium-sized ports are empowered to become the main innovation drivers for Blue Growth.

The doctoral thesis contributes to the theory in the following way:

First, the innovative digital maturity model for ports (incl. the DRIP model and the strategic graduation model towards smart port development) synthesises the resource-based view theory, the endogenous growth theory and the cluster theory to the maritime and, in particular, port sector under the new digitalisation paradigm. Additionally, the doctoral thesis extends the resource-based theory by explaining the role and significance of IT capabilities in the maritime and in particular port sector in connection with the digital transformation process in terms of the necessary bundling and combination of resources or technologies, respectively. Moreover, the digital maturity model for ports extends the resource-based view theory under the new digitalisation paradigm through the incorporation of the outlined enabling technologies and solutions in the frame of the innovative DRIP model (Articles II & III).

Second, the conceptualised digital maturity model for ports extends the supply chain and logistics management literature concerning the digital transformation in the maritime and especially port sectors by providing the theoretical foundation for the development towards smart ports, which, at the same time, as requested by Douaioui et al. (2018), contributes to the enhancement of port competitiveness and entrepreneurial collaboration with port stakeholders to achieve the horizontal and vertical integration of supply chains. Thus, through the processual digital maturity model for ports, the research gaps concerning the digital performance measurement in ports and the digital transformation of ports towards smart ports were closed (Articles II & III).

Third, the dissertation extends the transaction cost theory by showing how Blockchain and Smart Contracts, as well as corresponding technology-supported or -enabled new business models, in conjunction with business model innovation, decrease transaction and enforcement costs for ports, ship-owners, charterers and other maritime stakeholders in supply and value chains, which so far represented gaps in the literature (Articles IV & V).

Fourth, the doctoral thesis contributes to the supply chain and logistics management literature by showcasing how Blockchain and Smart Contracts foster entrepreneurial collaboration in maritime supply and value chains, as well as how small and medium-sized ports become enabled to better integrate themselves into smart supply and value chains through the adoption of this distributed ledger technology. The doctoral thesis demonstrated as well how Blockchain and Smart Contracts, through disintermediation in maritime supply and value chains and thus lower transaction costs, particularly enhance the competiveness, efficiency and participation of smaller and entrepreneurial actors (incl. small and medium-sized ports and other maritime stakeholders), whereby the adoption of this novel technology is enabled by lower total supply and value chain costs – which was previously not researched. Correspondingly, the investigated Blockchain and Smart Contract implementations in the frame of the charter-party contracting process and the cargo import in ports, as well as in the course of the innovative LBG MEC business model, represented research gaps in the literature which were filled by the doctoral thesis (Articles IV & V).

Fifth, the doctoral thesis contributes to the endogenous growth theory in the context of maritime science, since it clearly set out that the technological change implied by the theory, in times of the fourth industrial revolution (i.e. Industry 4.0), has to be associated with the digital transformation of maritime companies, such as the investigated ports – which was missing in the academic literature until now. Additionally, the doctoral thesis extends the endogenous growth theory by synthesising Blue Growth with economic growth in the sense of the theory, since both manifest in improved prosperity, greater employment and new job generation. Moreover, the doctoral thesis contributes to the endogenous growth theory and the new institutional economics theory by showing that the digital transformation as an internal force in companies of the maritime industry has a greater impact on Blue Growth than external forces coming from regulations that do not function as direct investments in human capital – here in the form of the TEN-T regulations and the IMO sulphur directives (Article I).

Sixth, the thesis contributes to the cluster theory by shedding light on the aspects of innovation networks, and based on this, pointing out the need for a symbiosis between smart specialization strategies and the digital transformation. Hence, the proposal from Kudrina et al. (2019) was extended through the provided theoretical foundation and empirical rationale for the advocated symbiosis. Particularly, this was underlined by the identification of digitalisation as the novel contemporary main driver for Blue Growth. Principally, smart specialization is necessary as the digital transformation process itself, as well as the related manifold digital technologies and their implementations, require skills, knowledge and capabilities on a superior level (Article I).

At the same time, the thesis contributes empirically to the research on the impact factors on regional economic growth by focusing on Blue Growth. The research results revealed that digitalisation has the greatest positive impact on Blue Growth and that the TEN-T regulations and IMO sulphur directives also, overall, have a positive, but softer impact. Thus, digitalisation, the TEN-T regulations and the IMO sulphur directives represent promoting drivers of Blue Growth, which so far was not investigated in the academic literature. The fact that digitalisation forms the main driver was verifiable among all the examined countries and sectors of the Blue Economy, whereas the influences of the TEN-T as well as the SECA Regulations and Global Sulphur Cap vary and thus are country and sector specific. Moreover, for some sectors, no or negative impacts from the TEN-T regulations and IMO sulphur directives were detectable (Article I).

The thesis makes the following policy recommendations and practical contributions:

The doctoral thesis contributes specifically to the goals of the EU Blue Growth Strategy, EU Integrated Maritime Policy and the Europe 2020 Strategy by providing a forecast analysis of the future Blue Growth potential in the SBSR and a related impact analysis of new contemporary main drivers, which also underlines the novelty of the thesis, since both has never been done before. Thereby, the critical sectors Aquaculture, Blue Biotechnology, Fishery, Seabed Mining, Offshore Oil & Gas, and Maritime Transport were identified. The findings suggest that policy measures should seek to further promote network activities within the blue sector in the SBSR, i.e. especially increase the integration of the identified sectors in the course of cross-border network activities in the region, in order to stimulate Blue Growth. Moreover, since digitalisation was detected as the main driver for the projected growth, it could be further deduced that policy measures should target to consider and promote within smart specialization strategies the digital transformation efforts of the maritime sector (Article I).

Besides this, the elaborated digital maturity model for ports supports port managers (authorities/operators) and policy makers as well as other port-related stakeholders in the course of decision-making, by assisting the identification and definition of a sustainable strategic direction for setting up the roadmap for the digital transformation in ports. Hence, the doctoral thesis delivered an effective and innovative strategic roadmap for the sustainable development towards smart ports (i.e. digital transformation) (Articles II & III).

Lastly, the doctoral thesis shows, for the first time, how Blockchain and Smart Contracts can be effectively implemented in the immediate or mediate port environment and thus how disintermediation is achieved in the maritime environment and in ports, as well as how this technology can be used to develop or support new maritime business models. Finally, the dissertation reveals how Blockchain and Smart Contracts improve the material, information and financial flows in maritime supply and value chains, and how especially smaller and weaker players (incl. small and medium-sized ports and other maritime stakeholders) can take advantage of the technology implementation, which again highlights the novelty of the doctoral thesis, since none of this has been investigated before (Articles IV & V).

The following limitations and research suggestions are associated with the thesis:

The results that refer to the two sectors Seabed Mining and Offshore Oil & Gas may have only limited significance and validity, since both sectors are underrepresented in the underlying sample of the study in Article I. Accordingly, this may be regarded as a methodological limitation that refers to the partial sample sizes of the sectors Seabed Mining and Offshore Oil & Gas (Article I). Nevertheless, desk research and additional expert interviews with representatives from the two sectors revealed that only a small number of companies exist in the SBSR that are clearly attributable to these two sectors. Thus, by taking this aspect into account, it can be postulated that all sectors of the Blue Economy are sufficiently captured within the corresponding study and that the sample reflects the economic situation in the SBSR (Article I). Furthermore, digital performance measurement in ports and especially in small and medium-sized ports was not researched in the academic and non-academic literature, which represents a general methodological limitation 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). The same applies to digital and Industry 4.0 readiness indexes and maturity models on the micro level. These models were primarily introduced in theory and practice to evaluate the performance of manufacturing firms, which is deeply rooted in the fact that they are the main target group in the context of the fourth industrial revolution. Hence, the overall logistics sector is relatively unaffected by digital and Industry 4.0 readiness indexes and maturity models (i.e. a general methodological limitation). Parallelisms exist with regard to scientific concepts that focus on the successive digital transformation of ports for the development towards smart ports (i.e. a general methodological limitation) (Articles II & III). Furthermore, Smart Contracts and Blockchains in the nexus of the maritime logistics sector, and, in particular, in the context of ports, have not been investigated so far in the academic literature, which implies once again a methodological limitation of the doctoral thesis due to the lack of prior research studies on the topic (Articles IV & V). In addition, the results that refer to the innovative LBG MEC business model have limitations that arise from the assumptions made (e.g. LBG is used to 100% after retrofit, and LBG consumption is equal to the previous consumption of ULSFO). Moreover, the central limitations of the corresponding study are related to the lack of available data. Since, so far, the LBG market in the context of the maritime industry is not established, no exact market data could be deduced. Thus, the presented LBG baseline price was derived from secondary data and represents a reasonable approximation only. Related to this is, once again, the lack of prior research studies on the topic, since LBG as a fuel for ships has not been comprehensively investigated (i.e. a general methodological limitation). Hence, only a few studies record approaches on the usage of LBG in the shipping sector (Article V).

Future research studies should target to elaborate development and promotion strategies for the maritime industry in the SBSR in order to reach a sustainable internationalisation of the Blue Economy, since other competing regions and maritime clusters in Europe have already implemented sustainability and marketing strategies (Article I). Furthermore, through the incorporation of PPIs that target to measure operational performance, it will be possible to investigate the latent relationship between the digital performance and operational performance of ports. (Articles II & III). In the frame of the conducted benchmarking, it was detected, among other things, that all investigated ports exhibit low digital readiness in the case of some digital technologies and solutions: Big Data & Predictive Analytics, Blockchain, AI, Robotics, Autonomous Solutions and CPS, Digital Twinning, and Augmented & Virtual Reality (incl. Simulation). Hence, future research activities should focalise on these digital technologies and solutions, since they have not or have hardly been implemented and used in ports (Article III). Lastly, future research studies should take a deeper look at the legal aspects that must be overcome in the introduction of Blockchains and Smart Contracting systems, as these have not been mooted in this doctoral thesis (Articles IV &V).

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Abstract

Smart Seaports as Innovation Drivers for Blue Growth

Seaports are the backbone of the transport network without which the worldwide economy could not exist in its present form. Indeed, seaports are the main hubs for commercial operations worldwide, and, as such, they contribute substantially to regional industries and development. Nevertheless, in times of increasing globalisation, the overall focus is most often centred on large ports. Besides the evergreen problems that are related to better supply chain integration and the identification of appropriate measures for the successful capture of a port's hinterland, especially small and medium-sized ports face novel contemporary challenges that are arising in conjunction with the Trans-European Transport Network (TEN-T) regulations, the intensified sulphur directives from the IMO and the progressive movement towards digitalisation. However, these new framework conditions not only pose risks but also can be seen as development opportunities for smaller ports. Particularly, digital transformation has the potential to become a vehicle to tackle the manifold challenges faced by small and medium-sized seaports and the Maritime Economy in general. In this context, the term "smart ports" is receiving growing attention in current scientific discussions. At the present time, the idea of a smart port as a fully automated port in which all devices are connected via the Internet-of-Things (IoT), and a network of smart sensors, actuators, wireless devices and data centres form the key infrastructure, still represents only a vision. However, true to the maxim "the journey is the reward", the promising development possibilities on the road towards smart ports target to stepwise increase ports' environmental and operational performance. Nevertheless, without the inclusion of small and medium-sized ports in this digital transformation process, the innovative idea of smart ports remains unachievable. The realisation of this innovative venture is aggravated by the fact that the research on small and medium-sized ports is just at the beginning. Accordingly, scientific studies have pointed out the common lack of empirical research that incorporates the specific and often regionally bound characteristics and perspectives of smaller ports. Hence, different researchers emphasise that diverse gaps exist in the form of missing models and concepts in relation to small and medium-sized ports.

Correspondingly, the doctoral thesis positions itself in this niche and thus is driven by the motivation to make a sustainable contribution to the further development of this maritime science field. Simultaneously, research efforts and activities directed at this object of study inevitably contribute to the EU Blue Growth Strategy, which targets to support sustainable growth in the marine and maritime sector. *Vice versa*, the Blue Growth Strategy contributes to the EU's Integrated Maritime Policy to achieve the goals of the Europe 2020 Strategy for smart, sustainable and integrative growth. Accordingly, the objective of the dissertation is to develop a conceptual and processual model that ensures a sustainable digital transformation, so that small and medium-sized ports in the South Baltic Sea Region (SBSR) are enabled to become the main innovation drivers for smart regional growth in the sense of the EU Blue Growth Strategy. In the scientific discourse of the doctoral thesis, the research strategy of methodological triangulation was applied, which builds upon quantitative and qualitative data from surveys, expert interviews, case studies, workshops, focus group meetings, field research and observations collected and produced in the frame of several EU projects.

The results show that, overall, the future Blue Growth potential in the SBSR can only be evaluated as moderate and that, among other things, especially in the case of the

Maritime Transport sector, there is an evident need for action in order to systematically foster smart regional growth in the SBSR, whereby digitalisation has been identified as the most important driver. Subsequently, the results highlight the Digital Readiness Index for Ports (DRIP), which allows for digital performance measurement and the digital readiness indexing of ports. Furthermore, the strategic graduation model towards smart port development is showcased, which enables the classification of ports according to their digital performance, the identification of the individual strategic digital positioning of ports and the derivation of a corresponding strategic direction for the sustainable development towards smart ports (i.e. digital transformation in ports). Moreover, through benchmarking, it was detected that ports show low digital readiness, among other things, in the case of Blockchain technology (incl. Smart Contracts). Thus, further research findings refer to three different case studies concerning Blockchain and Smart Contracts. The first case puts the emphasis on the charter-party contracting process (i.e. macro-logistics level) and its optimisation through the application of this distributed ledger technology, which manifests, among other things, in direct positive economic impacts for ship-owners due to the exclusion of shipbrokers, but also has indirect positive effects for all process participants due to spill-over effects. In contrast, the second case study focused on the cargo import in a medium-sized port (i.e. micro-logistics level) and revealed how the internal processes can be improved and thus, among other things, transaction and enforcement costs decrease through the Blockchain and Smart Contract implementation. Additionally, both cases jointly show how Blockchain and Smart Contracts foster entrepreneurial collaboration in maritime supply chains and how small and medium-sized ports become enabled to better integrate themselves into smart supply chains. The last case examined an innovative business model with a special focus on liquefied biogas (LBG). The results highlight that Blockchain and Smart Contracts foster the implementation of the elaborated LBG Maritime Energy Contract (MEC) business model as well as the optimisation of underlying value chain operations.

Finally, it was concluded that through the supported sustainable digital transformation and the special focus on specific digital enabling technologies, such as Blockchain and Smart Contract, small and medium-sized ports are empowered to become the main innovation drivers for Blue Growth. The developed DRIP model and the strategic graduation model towards smart port development culminated in a digital maturity model for ports, which represents a synthesised, conceptualised and processual model that sets up the roadmap for the sustainable digital transformation of ports and thus contributes to the established organisational theories in the frame of maritime economics, in which a respective research gap existed. In addition, through the determination of the future growth potential of the Maritime Economy in the SBSR and the derivation of urgent needs for action concerning specific sectors, as well as the identification of the main drivers for sustainable economic development of the region, the doctoral thesis contributes specifically to the EU Blue Growth Strategy, the EU Integrated Maritime Policy and the Europe 2020 Strategy. Lastly, through this doctoral thesis, ports, organisations that belong to the Blue Economy and further maritime stakeholders receive comprehensive insights into the potentials of the Blockchain and Smart Contract technology, the digital transformation process and the contemporary main drivers for smart, sustainable and integrative growth.

Lühikokkuvõte

Nutikad meresadamad kui sinist majanduskasvu vedav innovatsioon

Meresadamad, mis moodustavad tänapäeval ülemaailmse majanduse transpordivõrgu selgroo, ei saa enam jätkuvalt eksisteerida senisel kujul. Kuigi meresadamad on keskse tähtsusega maailmakaubanduses, panustavad need oluliselt ka regionaalsesse tööstusesse ja arengusse. Sellele vaatamata keskendutakse suureneva globaliseerumise ajastul reeglina vaid suursadamatele. Lisaks teadaolevatele probleemidele, mis puudutavad paremat tarneahela integratsiooni ja sobilike meetmete identifitseerimist äärealade väikeste ja keskmise suurusega sadamate rakendamisel, ollakse silmitsi uudsete kaasaegsete väljakutsetega, mis tõusevad esile koos üleeuroopalise transpordivõrgu (TEN-T) regulatsioonidega, Rahvusvahelise Merendusorganisatsiooni (IMO) poolsete tugevdatud väävliemissiooni piiramise direktiividega ja üha süveneva digitaliseerimisega. Vaatamata sellisele uuele olukorrale, ei tule neid uusi raamtingimusi näha kui riske, vaid kui arenguvõimalusi väikesadamatele. Just digitaalne transformatsioon omab potentsiaali olla edasiviivaks jõuks nendele keerukatele väljakutsetele, mis puudutavad nii väike- ja keskmise suurusega sadamaid kui ka meremajandust üldiselt. Selles kontekstis saab termin 'nutikas sadam' käimasolevates teaduslikes aruteludes üha kasvavat tähelepanu. Käesoleval ajal aga – idee nutisadamast kui täielikult automatiseeritud sadamast, kus kõik seadmed on ühendatud asjade interneti (IoT) kaudu nutisensorite ja ajamitega, kus nii juhtmevabad seadmed kui ka andmekeskused moodustavad võtmetaristu – on siiski visioon. Samas tuleb pidada tõeseks maksiimi "teekond on teelise tasu" ja kasutada lubavaid arenguvõimalusi teel väikesadamate eesmärkide saavutamiseks. Samm-sammult tuleb suurendada nende keskkonna- ja tootmisjõudlust. Selleks edasiliikumiseks on oluline kaasata väike- ja keskmise suurusega sadamad eespool mainitud digitaalse transformatsiooni protsessi, vastasel juhul jääb uuenduslik idee nutisadamatest saavutamatuks. Antud uue innovaatilise ettevõtmise teostatavus põhineb ka asjaolul, et teaduslikud uurimused väike- ja keskmise suurusega sadamate kohta on alles algusjärgus. Varasemad uuringud on näidanud selliste empiiriliste uuringute puudumist, mis haaravad spetsiifilisi piirkondlikke näitajaid, et aidata iseloomustada väiksemate sadamate tulevikku. Need uuringud toovad välja paljud lüngad, mis puudutavad nii mudeleid kui ka vastavaid mõisteid seoses väike- ja keskmise suurusega sadamatega.

Eeltoodu põhjal paigutub käesolev doktoritöö esitatud nišši ja teeb jätkusuutliku panuse antud merendusvaldkonna edasiseks arenguks. Autori teaduslikud jõupingutused ja tegevused antud uuringu eesmärgil panustavad vältimatult ka Euroopa Liidu (EL) sinise majanduskasvu strateegiasse, mille eesmärgiks on toetada kestlikku kasvu sadamate ja merenduse sektoris. Ning vastupidiselt – sinise majanduskasvu strateegia panustab EL-i Integreeritud Merenduspoliitikasse, et saavutada Euroopa 2020 Strateegia aruka, kestliku ja integreeriva kasvu eesmärke. Doktoritöö eesmärgiks on arendada välja kontseptuaalne ja protsessuaalne mudel, mis kindlustab kestliku digitaalse transformatsiooni nii, et väike- ja keskmise suurusega sadamad Läänemere lõunapiirkonnas (SBSR) saavutavad võimekuse olemaks peamised regionaalsed aruka kasvuga seotud innovatsiooni edasiviijad Euroopa Liidu sinise majanduskasvu strateegia mõttes. Doktoritöö teaduslikus diskursuses rakendati metodoloogilise triangulatsiooni uurimisstrateegiat, milles kasutati nii kvantitatiivseid kui ka kvalitatiivseid andmeid, mis põhinevad küsitlustel, ekspertintervjuudel, juhtumiuuringutel, töötubadel, fookusgrupi

kohtumistel, välitöödel ning ka vaatlustel. Kõik need andmed on kogutud ja saadud mitmete EL-i projektide raames.

Tulemused näitavad, et üleüldist tuleviku sinise majanduskasvu potentsiaali saab hinnata Läänemere lõunapiirkonnas vaid mõõdukaks. Iseäranis meretranspordi alamsektori korral on ilmne, et eksisteerivad vajadused tegevusteks, mis süstemaatiliselt kiirendaksid arukat regionaalset kasvu SBSR piirkonnas ning digitaliseerimine on olulisim sealse arengu edasiviija. Tulemused näitasid ka Sadamate Digitaalse Valmisoleku Indeksi (DRIP), mis kindlustab digitaalse jõudluse mõõtmist ja sadamate digitaalset valmisolekut, kasutamise vajalikkust. Nutikate sadamate arenguks loodud strateegilise gradatsiooni mudelit demonstreeritakse kui vahendit sadamate klassifitseerimiseks vastavalt nende digitaalsele jõudlusele, selleks, et tuvastada sadamate strateegiline digitaalne paigutumine ja tuletada vastav strateegiline suund nutisadama kestlikuks arenguks. Mõõtmiste tulemusena selgus, et uuritud sadamatel on madal digitaalne valmisolek (lisaks muudele aspektidele) ka blokiahela rakendamiseks (kaasaarvatud nutikate lepingute puhul). Uurimistulemused põhinevad kolmel erineval juhtumiuuringul, mis käsitlevad blokiahelat ja nutikaid lepinguid. Esimeses juhtumis on rõhuasetus tšarterlepingu protsessil (st. makrologistika tasemel) ja optimeerimisel läbi vastava hajutatud pearaamatu tehnoloogia rakendamise. Sellel on otsene positiivne majanduslik mõju laevaomanikele tänu laevavahendajate välistamisele, aga samuti ka kaudne positiivne efekt kõikidele protsessis osalejatele läbi võimalike kaasnevate ülekandumisefektide. Teine uuring keskendus kauba impordi juhtumile keskmise suurusega sadamas (st. mikrologistika tasemel) ja näitas, kuidas sisemisi protsesse võib parendada nii, et teiste seas ka transaktsiooni ja järelevalve kulud vähenevad läbi blokiahela ja nutikate lepingute kasutuselevõtu. Olulisena tuleb välja tuua, et mõlema juhtumi puhul ilmnes, kuidas blokiahela tehnoloogia ja nutikad lepingud soodustavad ettevõtlikku koostööd merenduse tarneahela protsessis ning kuidas samaaegselt väike- ja keskmise suurusega sadamad saavad võimekuse enda paremaks integratsiooniks tarneahelatega. Kolmas juhtumiuuring keskendus innovaatilisele ärimudelile koos erilise tähelepanuga vedeldatud biogaasil (LBG). Selle uuringu tulemused näitavad, et blokiahel ja nutikad lepingud soodustavad väljatöötatud LBG Merenduse Energia Lepingu (MEC) ärimudeli kui ka tarneahela optimeerimise rakendamist.

Kokkuvõttes järeldati, et läbi sadamate kestliku digitaalse transformatsiooni toetamise, kus fookus asetseb digivõimekusi aktiveerivatel tehnoloogiatel nagu blokiahel ja nutikas leping, tekibki väikese ja keskmise suurusega sadamail võimekus saada peamiseks sinise majanduskasvu innovatsiooni elluviijateks. Doktoritöös loodud DRIP mudel ja strateegilise gradatsiooni mudel nutisadamate arenguks formeerisid koos sadamate digitaalse küpsuse mudeli, mis koosneb sünteesitud, kontseptualiseeritud ja protsessimudelist. Uus mudel loob raamistiku sadamate digitaalseks transformatsiooniks ning samas panustab tunnustatud organisatsiooniteooriatesse läbi merendusmajanduse, mis täidab ka vastava uurimislünga. Lisaks, läbi merendusmajanduse tuleviku kasvupotentsiaali määramise Läänemere lõunapiirkonnas ja sealsete spetsiifiliste alamsektorite pakiliste vajaduste välja selgitamise, mis on vajalikud regiooni kestvaks majandusarenguks, panustab antud doktoritöö oluliselt EL-i sinise majanduskasvu strateegiasse, EL-i Integreeritud Merenduspoliitikasse ja Euroopa 2020 Strateegiasse. Sadamad ja organisatsioonid, mis kuuluvad sinisesse majandusse, samuti tulevased sidusrühmad, saavad ulatusliku ülevaate blokiahela ja nutikate lepingute tehnoloogia potentsiaalist, digitaalse transformatsiooni protsessist ning aruka, kestva ja integreeriva kasvu kaasaegsetest liikumapanevatest jõududest.

Appendix 1

Publications

Publication I

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BLUE GROWTH POTENTIAL IN SOUTH BALTIC SEA REGION

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The Baltic Sea Region (BSR) stands for a flagship maritime region in Europe with dominating SME sector. Nevertheless, compared with other European regions, the cooperation and promotion activities of companies that belong to the Blue Economy in South Baltic Sea Region (SBSR) are not sufficient. As a response to this, the EU-project INTERMARE South Baltic aims to support the maritime economy in the SBSR by the creation of a network of companies and stakeholders.

In line with the project, this study aims to analyse the future potential of the maritime economy and to identify trends that impact the sustainable development of the blue sector in SBSR. Based on primary data from a SBSR wide survey, descriptive statistical analysis is applied and Compound Annual Growth Rate is used as an indicator. The findings reveal need for actions regarding the sub-sectors Transport, Offshore oil & gas, Aquaculture, Fishery, Mineral resources and Biotechnology.

Keywords: Maritime Economy, Blue Growth, Sustainable Development, SMEs, Internationalisation, Predictive Analysis

1. Introduction

If all economic activities that depend on the sea would be cumulated, the so-called "Blue Economy" of the EU is responsible for about 5.4 million jobs and a gross value added of almost 500 billion EUR per year (EC, 2012). Thereby, especially the Baltic Sea Region (BSR) has still a forerunner position and thus, stands for a flagship maritime region in Europe in terms of good economic, social and environmental performance (Gerlitz *et al*., 2017). Following the current "State of the Region Report" (Ketels *et al*., 2017), the BSR generated in 2015 an annual GDP of about 2,000 billion EUR, which is equivalent to 12.5% of the EU-28 economy. Therefore, also in the South Baltic Sea Region (SBSR), the maritime economy is one of the most prospective area of development. However, compared with other European regions, the cooperation and promotion activities of companies that belong to the Blue Economy in the SBSR are not sufficient, which impairs the competiveness and sustainable development of the entire region. Furthermore, despite the strong lobbing and support coming from the regional authorities for the intensive development of the maritime economy and industries, there is still a lack of international instruments in the SBSR that support the internationalisation activities of SMEs.

As a response to this, the EU-project INTERMARE South Baltic – part-financed by the ERDF (INTERREG South Baltic Programme 2014–2020) – aims to support the maritime economy in the SBSR by the creation of a network of companies and stakeholders under the common brand "INTERARE South Baltic", which will be easily recognised in the region and in other European and global markets. In order to push forward this primary objective, within the EU-project INTERMARE South Baltic, companies from the SBSR that belong to the maritime economy – which we define in accordance to the EU Blue Growth Strategy – were surveyed.

In line with the project, the present study with a focus on SMEs aims to identify and analyse (1) the future potential of the maritime economy in SBSR in relation with the demand from other markets outside the region, and (2) potential trends that have an impact on the sustainable development of the blue sector in SBSR. Hence, the present study grounds on the survey from the EU-project INTERMARE South Baltic, and thus, reveals the empirical results thereof, which leads to the achievement of the envisaged objective of identification and analysis of the future potential as well as trends that affect the Blue Economy in the SBSR.

The paper is structures as follow: In the second chapter, the theoretical background is drawn. The third section presents the applied research methodology, which includes an exposition of the data collection procedure, the data analysis measures as well as sample description. Building upon this, the main research results are showcased in the fourth chapter, which embraces a detailed analysis of the future potential of the blue sector as well as potential arising market trends that affect the maritime economy in the SBSR. The paper rounds up with a discussion and conclusion.

2. Theoretical Background

Through intensifying globalisation and arising global networks, new social and environmental challenges jeopardize innovation and growth opportunities in different markets. Indeed, this is especially true for the SME sector and the performance of individual regions in the EU (Prause *et al*., 2018). According to European Commission (2018a), more than 99% of all companies in the EU represent micro and SMEs. In 2015, nearly 23 million SMEs generated about 3.9 trillion EUR in value added and are responsible for approx. 90 million jobs, which mirrors an essential source of entrepreneurial spirit and innovation that is essential for the competitiveness of the EU. Therefore, SMEs are regarded as the backbone and driver of regional and national economies. Thus, there is a need to support SMEs and entrepreneurship, since they have a crucial role in generating economic growth, triggering innovations, attracting new investments and businesses, enabling clusters to evolve, ensuring employability and social integration (Dutta *et al*., 2018; Prause *et al*., 2018; EC, 2013a, 2013b, 2017; Eurostat, 2018). Hence, also in the EU Strategy of the BSR, SMEs are considered as accelerators for innovative products and services of high quality (EC, 2018b).

In the globalized knowledge society, prosperity and competitiveness of regions depend on local strengths and innovation power of local economies. Accordingly, future success will be given to companies and urban or rural regions that are able to reach global standards and join global networks as well as markets. Regional development is an innovation process, which fundamentally depends on interactions. Interaction is the source for acquiring innovation and knowledge and thus, for the economic growth and sustainable development of regions (Goddard, 1997).

The well-known cluster concept of Michael E. Porter highlights the regional aspect of a cluster by defining it as “a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities” (Porter, 2000). Accordingly, the performance and competitiveness of a cluster depends on its internal characteristics – commonalities and complementarities. Thereby, the majority of the related literature on cluster theory highlights the inherent spatial aspect of clusters by explaining why a group of companies emerge in a particular place and why they are bound to this specific place. Next to this, its external environment determines a cluster. One of most important reasons for the development of a cluster is that companies in a cluster are more productive and innovative compared to the situation of isolation. With other words, the cluster approach give competitive advantage, because it decreases the entry barriers for new business creation relative to other sites (zu Köcker, 2009). By focalising on regional innovation and networking, Goddard proposed the idea of regional knowledge or innovation networks where only those firms will be successful in a globalized economy that fulfil global standards, enter global networks and develop operational models that adapt quickly to changing market conditions and trends (Goddard, 1997 & 2000). Hence, collaborative innovation activities of SMEs with other companies and stakeholders represent key success factors to compete in the global economy, where cluster and network initiatives form the ground base. Keeping this in mind, it can be stated that the EU-project INTERMARE South Baltic is on the right track, since it aims to support the maritime economy in the SBSR by the creation of a network of companies and stakeholders under the common brand “INTERARE South Baltic”, which will be easily recognised in the region and in other European and global markets.

3. Method

3.1. Data collection

Empirical data collection activities were conducted between the 12th of November 2018 and 11th of June 2019, which represents a total data collection duration of about 7 month. The main target group were SMEs from the maritime sector that are located in SBSR. Accordingly, next to defined SMEs, this includes as well start-ups and micro firms, whereby all of these relevant companies must be attributable to the maritime economy in SBSR. Nevertheless, from the empirical data collection activities large companies were not precluded, since the objective of the present investigation is to "analyse the future potential of the maritime economy in SBSR", which implies that the maritime economy as a whole will be analysed – which vice versa leads to the inclusion of larger companies next to SMEs. The geographical scope of the empirical data collection activities is framed through all adjacent SBSR countries, namely Germany, Lithuania, Poland, Denmark and Sweden.

In order to define the maritime economy more detailed, on the basis of the elaborated findings of the preceding desk research, the decision was made to differentiate the maritime economy according to the Blue Growth Strategy of the EU. According to this definition, the Blue Economy consist of the following nine sub-sectors (EC, 2014):

- Aquaculture;
- Biotechnology;
- Coastal and maritime tourism;
- Fishery;
- Mineral resources;
- Offshore oil and gas;
- Renewable energy;
- Shipbuilding and ship repair;
- Transport (cargo / ferry).

In general, the European Commission in its Blue Growth Strategy differentiates the Blue Economy according to five focus sectors only – Renewable energy, Biotechnology, Coastal and maritime tourism, Aquaculture, Mineral resources – and mentions the other four above listed fields – Shipbuilding and ship repair, Transport, Fishery, Offshore oil and gas – as "other sectors" of the Blue Economy, since they are also crucial for value and job generation. Accordingly, this present research study follows a more detailed and profound definition of the Blue Economy by taking all nine sub-sectors into account. In contrast to this, the European Commission further refers in the context of the Blue Growth Strategy to so-called "essential components" in order "to provide knowledge, legal certainty and security in the blue economy", which directly concerns to "marine knowledge", "maritime spatial planning" and "integrated maritime surveillance" (EC, 2019). Since, firstly, these "essential components" represent in most cases non-profit orientated or state-owned and -governed/run institutions (like: universities, maritime schools, customs, water police, etc.) and, secondly, the main target group for the underlying research mainly refers to profit- and market-orientated firms, these particular fields had been excluded from the present investigation. Otherwise, the problem of differentiation between profit-orientated or market-orientated firms and non-profit orientated organisations would cause and call for further limitations. However, through the limitation of and focus on these nine sub-sectors, a more sharpened and clear differentiation is ensured. Furthermore, the inclusion of these three "essential components" to the scope of the defined target group would not match the overall objective of the present investigation: identification and analysis of the future potential of the maritime economy in SBSR in relation with the demand from other markets outside the region.

On the basis of this envisaged objective and building upon on the findings, which had been elaborated from a preceding desk research, a survey was elaborated. Accordingly, the objective of the survey "Future Potential of Maritime Economy in South Baltic Sea Region" was to identify and analyse the future potential of – as well as trends that currently or in the near future affect – the Blue Economy in SBSR. Thereby, it needs to be noted, that the survey developed for this purpose was based on the premise that the analysis is carried out in the SBSR, but in relation with the demand outside the region. Therefore, all in all, the related data collection activities mainly targeted to generate primary data.

In the frame of the pre-test, 31 participants from Germany, Lithuania, Estonia, Poland, Sweden and Denmark were involved. The pre-test of the online survey was conducted to establish content validity from both INTERMARE South Baltic project partners (PPs) as well as market actors. Furthermore, the major focus of the pre-test was to guarantee clarity, value as well as importance of the survey items. In addition, the pre-test procedure ensured (1) supplementation of aspects that so far have been neglected, (2) verification of the comprehensibility of questions, (3) improvement of the survey regarding structure and design, as well as (4) determination of the needed average time for survey completion (Kromrey, 2013; O'Leary, 2017; Rüdiger *et al.*, 2011).

Hence, the empirical data collection was initially exclusively online-based, whereby the access to the online survey was provided via a specific link to the website. The invitation to the online survey reached the target group via E-Mails, which was ensured by the support of two previously selected PPs. By doing so, the following key advantages could be perceived through the online-based data collection: (1) ensuring that the survey was carried out anonymously, (2) exclusion of influencing the respondents due to the survey situation, (3) facilitation of respondents' time-based flexibility, and (4) generation of an adequate sample (Döring & Bortz, 2016; Diekmann, 2007; O'Leary, 2017; Schnell *et al.*, 2004). Possible disadvantages of the online-based survey could be reduced or eliminated. For instance, in order to prevent misuse in the form of a multiple participation, the inclusion of cookies was conducted (Schnell *et al.*, 2004). Furthermore, comprehension problems – which can be clarified for example in an oral or telephone survey – could be largely ruled out, since the topic and its essential contents were explained at the beginning of the survey. On the other hand, this issue was also tackled by the circumstance that the previous identification of potential participants was individual performed by each PP according to the definition of the target group. Against this background, it can be assumed that the participants in the survey are familiar with the topic (Philipp et. al., 2019a).

At the end of the data collection phase, in order to achieve an adequate response rate in some target countries, companies were contacted additionally via telephone, during face-to-face meetings, training events or conferences. However, the data collection process was anonymised, and no one else – with exception of the representatives of the EU-project INTERMARE South Baltic – could see the answers or information that had been provided by the participants. Furthermore, the participants of the online survey were informed on the first page of the online survey about the topic, aim and purpose of the survey and the EU-project INTERMARE South Baltic, as well as data processing. In addition, the participants had been informed that participation is voluntary. Moreover, it was indicated that the provided data was always treated confidentially and for further purposes aggregated anonymously in order to make the data usable for research and scientific purposes only. In sum, these and further given information resulted in the option for the participants to agree on the indicated consent form and provided information, or not. All these explanations and the declaration of consent were highlighted and implemented in order to be in line and to show compliance with the current EU data protection legislation (ibid.).

3.2. Data analysis

After successful data collection phase, seamlessly, data analysis measures were performed. The empirical data analysis activities were finished by the middle of June 2019. Instruments that had been used in the frame of the data analysis in this present study embrace mainly descriptive statistical data analysis that had been applied on the basis of the received quantitative data. In the course of descriptive statistical analysis, primary the location parameter arithmetic mean was used. In addition, the future market potential analysis was performed through the usage of the "Compound Annual Growth Rate (CAGR)" in order to measure the future growth potential of the Blue Economy in SBSR in relation with demand outside this region. The CAGR was chosen, since this key performance indicator represents an essential figure for the consideration of investments, market developments, sales, etc. in business administration as well as economics. The CAGR constitute the average annual growth of a given variable, here: turnover. The formula for the calculation of the CAGR has the following form:

$$CAGR(t_0, t_n) = \left(\frac{V(t_n)}{V(t_0)}\right)^{\frac{1}{t_n - t_0}} - 1, \quad (1)$$

where

$CAGR$ Compound Annual Growth Rate;
$V(t_0)$ Initial value;
$V(t_n)$ End value;
$t_n - t_0$ Number of years.

3.3. Sample description

During the data collection phase, 362 companies accessed the online survey via the link to the website. Thereby, 362 represents only the number of companies that have accessed the online survey, even more had been contacted. However, a total of 133 companies have fully participated in the underlying survey.[1] The population is made up of companies that are active in the maritime sector – according to the defined target group: Blue Economy – and are located in the eligible catchment area of the "INTERREG South Baltic Programme (2014–2020)", which is further differentiated by the five eligible regions/countries: Germany, Lithuania, Poland, Denmark and Sweden. The description of the underlying sample is given in Table 1. According to Table 1, the sample size of 133 companies consist of 36 firms from Germany, 28 participants from Lithuania, 27 companies from Poland, 23 firms from

[1] This represents a dropout rate of 63.26%.

Denmark and 19 participants from Sweden. Through the comparison of the different nine sub-sectors, it is noticeable that both the sub-sectors “Transport” (42.105%) as well as “Shipbuilding and ship repair” (26.316%) are overrepresented in the overall sample.

Table 1. Sample description

	SBSR		Germany		Lithuania		Poland		Denmark		Sweden	
	hi	**fi, %**	hi	fi, %	hi	fi, %	hi	fi, %	hi	fi, %	hi	fi, %
Number/proportion of participants	**133**	**100.000**	36	100.000	28	100.000	27	100.000	23	100.000	19	100.000
Maritime sector												
Aquaculture	**8**	**6.015**	4	11.111	1	3.571	3	11.111	0	0.000	0	0.000
Biotechnology	**6**	**4.511**	1	2.778	1	3.571	4	14.815	0	0.000	0	0.000
Coastal & maritime tourism	**10**	**7.519**	3	8.333	2	7.143	1	3.704	3	13.043	1	5.263
Fishery	**6**	**4.511**	4	11.111	2	7.143	0	0.000	0	0.000	0	0.000
Mineral resources	**3**	**2.256**	2	5.556	1	3.571	0	0.000	0	0.000	0	0.000
Offshore oil & gas	**2**	**1.504**	0	0.000	1	3.571	0	0.000	1	4.348	0	0.000
Renewable energy	**7**	**5.263**	2	5.556	2	7.143	2	7.407	1	4.348	0	0.000
Shipbuilding & ship repair	**35**	**26.316**	11	30.556	3	10.714	10	37.037	5	21.739	6	31.579
Transport (cargo/ferry)	**56**	**42.105**	9	25.000	15	53.571	7	25.926	13	56.522	12	63.158
Company size												
Micro	**33**	**24.812**	6	16.667	11	39.286	14	51.852	1	4.348	1	5.263
Small	**33**	**24.812**	9	25.000	9	32.143	9	33.333	5	21.739	1	5.263
Medium	**55**	**41.353**	18	50.000	4	14.286	4	14.815	15	65.217	14	73.684
Large	**12**	**9.023**	3	8.333	4	14.286	0	0.000	2	8.696	3	15.789
Year of foundation												
before 2004	**98**	**73.684**	31	86.111	17	60.714	11	40.741	22	95.652	17	89.474
2004 - 2008	**9**	**6.767**	2	5.556	2	7.143	3	11.111	0	0.000	2	10.526
2009 - 2013	**8**	**6.015**	2	5.556	3	10.714	2	7.407	1	4.348	0	0.000
2014 - 2018	**18**	**13.534**	1	2.778	6	21.429	11	40.741	0	0.000	0	0.000

4. Findings

4.1. Future potential

In order to identify the future potential of the maritime economy in SBSR, in the underlying online survey, participants that represent the Blue Economy of SBSR – according to the defined target group – had been asked to estimate their company’s turnover growth rate (in %) for the next five years (2019 to 2023) according to different geographical markets: Regional, National, BSR, Europe, Africa, Asia, Australia, North America and South America. This was done, since the objective was to carry out the investigation in SBSR, but in relation with the demand outside the region. Therefore, the nine examined markets are separated in domestic markets (incl. Regional, National, BSR) and international markets (incl. Europe, Africa, Asia, Australia, North America, South America), whereby the latter case encapsulates the demand outside the SBSR.

In the frame of the BSR as a market, the decision was made to incorporated this specific market in the category of domestic markets, since from the perspective of the maritime economy in SBSR, the BSR mainly represents to a large extend the home market. Another potential overlap exist in the course of the analysed European market, since the European market incorporates also the BSR market. However, the BSR market represents only a small part of the entire European market, and thus, the European market was logically included in the category of international markets. Through the aggregation of the received data in case of the six continental markets (i.e. Europe, Africa, Asia, Australia, North America, South America), it became possible to derive conclusions about the holistic worldwide demand that is attributable to the maritime economy of SBSR.

Moreover, it should be noted that in the following, firstly, the received results are presented in relation to country differentiation/affiliation (incl. all participating countries that belong to the eligible area of the “INTERREG South Baltic Programme”: Germany, Lithuania, Poland, Denmark and Sweden), and afterwards, in contrast to the differentiation of the respective nine sub-sectors (i.e. Aquaculture, Biotechnology, Coastal and maritime tourism, Fishery, Mineral resources, Offshore oil and gas, Renewable energy, Shipbuilding and ship repair, Transport) of the Blue Economy. Accordingly, through the aggregation of the received results of all five countries (Germany, Lithuania, Poland, Denmark and

Sweden), the holistic perspective of the maritime economy from SBSR as a whole is gathered, which is equal to the aggregation of the received results of all investigated nine sub-sectors (Aquaculture, Biotechnology, Coastal and maritime tourism, Fishery, Mineral resources, Offshore oil and gas, Renewable energy, Shipbuilding and ship repair, Transport). Thus, on the one hand, the aggregation of the received results from national level, and on the other hand, the aggregation of received results from sub-sector level, form the study sample: maritime economy in SBSR – neglecting the circumstance that in the following in some cases only the SBSR or maritime economy alone is showcased.

The duration of five years (2019 to 2023) was chosen, since longer periods are often associated with higher uncertainties. Accordingly, in order to have more reliable results, the duration of five years was set, which further fosters the trust in the following concluding remarks. On the other hand, through this, urgent and rapid need for actions are better identifiable.

The received data through the online survey in form of estimated company's turnover growth rate (in %) for the next five years (2019 to 2023) was processed through descriptive statistical analysis by using the arithmetic mean. Thereby, turnover growth rates over 20% and under -20% had been considered as outliers and therefore, had been excluded from further analysis. In this context, it should be noted that in the survey, no participating company estimated a growth rate of less than -20%. Only in some cases, very optimistic estimations with more than 20% had been indicated by some firms (hi = 7). Deeply rooted in the fact that these too optimistic answers had been considered as outliers, it can be stated that the overall analysis of the future potential of the maritime economy in SBSR follows rather a pessimistic perspective, which means that the gained results are closer to more realistic market conditions. Since the received arithmetic mean values refer to the expected total growth rates of the entire period of five years (2019 and 2023), the CAGR was calculated and further used for interpretations. Accordingly, in this study, for the analysis of the future potential of the maritime economy in SBSR, the CAGR is used as the representative indicator.

Domestic markets

The elaborated results for the domestic markets differentiated according to the five nations of the SBSR are summarised in Figure 1. According to Figure 1, from a holistic perspective (i.e. maritime economy from SBSR as a whole), the national markets (1.274%) and the entire BSR market (1.213%) are associated with the highest turnover growth rates, since the CAGR for the regional markets in the near proximity of the Blue Economy firms is a little bit lower with 1.178%, but still can be evaluated as moderate. Therefore, it can be stated that especially the domestic markets play a crucial role in the future for maritime economy companies from the SBSR, based on aggregated results.

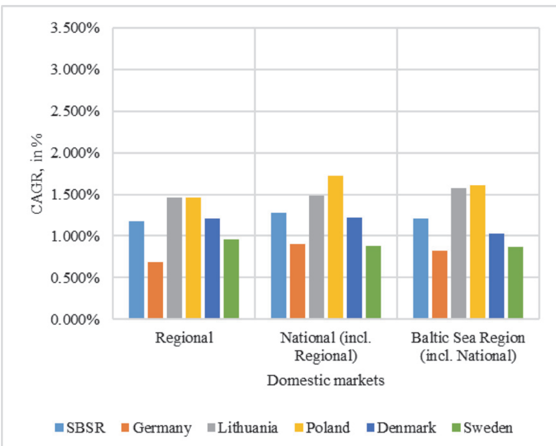

Figure 1. CAGR on national level – domestic markets

By having a closer look on the results on respective national level, it becomes obvious that Swedish and especially German companies of the maritime economy, evaluate the annual turnover growth rates (CAGRs) on all three differentiated domestic markets (i.e. Regional, National, BSR) rather pessimistic (SE: Regional = 0.957%, National = 0.884%, BSR = 0.865%; DE: Regional = 0.681%, National = 0.899%, BSR = 0.822%), compared to the Blue Economy firms from Lithuania and Poland (LT: Regional = 1.466%, National = 1.479%, BSR = 1.579%; PL: Regional = 1.466%, National = 1.722%, BSR = 1.61%), whereby the obtained respective values from Danish firms lay in the middle (Regional = 1.215%, National = 1.217%, BSR = 1.026%). Especially, the CAGR that refers to maritime economy firms from Germany in relation to the regional markets (0.681%) can be evaluated as too low. Against this, the CAGRs of Lithuania and Polish Blue Economy companies with an average of 1.5% (or more) reveal that for these companies the domestic markets (i.e. Regional, National, BSR) are of high importance in the future. Furthermore, in case of Lithuanian maritime economy firms, it becomes obvious that that through the increase of the geographical scope of the market, the CAGR increases as well, whereby vice versa, in the case of Swedish Blue Economy firms with an increase of the geographical scope of the market, the CAGR decreases.

The results for the domestic markets differentiated according to the nine sub-sectors of the Blue Economy are summarised in Figure 2. According to Figure 2, it can be concluded that the importance of the three different domestic markets among the nine sub-sectors of the Blue Economy is quite unbalanced. For instance, for the maritime economy sub-sector Aquaculture, a moderate CAGR on the national markets (1.199%) and to a certain extent on the BSR market (1.029%) was calculable, whereby the regional markets for Aquaculture companies from the SBSR are associated with a low future potential, since the expected annual growth rate with 0.852% is quite low. Similarities are visible for the sub-sector Coastal & maritime tourism, since the CAGR in case of the national markets represents only 0.787%, whereby a moderate level of the CAGRs was detected for the BSR market (1.013%), and to a certain extent for the regional markets (0.953%). Even more dramatic are the findings that are related to the sub-sector Mineral resources, since all predicted CAGRs for the three domestic markets are under 0.8% (Regional = 0.787%, National = 0.69%, BSR = 1.362%) – whereby obviously through the increase of the geographical scope of the market, the CAGR decreases, too. Also for the sub-sector Renewable energy, the CARGs that refer to the regional (0.884%) and national markets (0.916%) cannot convince; only for the BSR market (1.21%), the annual turnover growth rate (CAGR) promise acceptable moderate growth in the near future – whereby obviously through the increase of the geographical scope of the market, the CAGR increases as well. Slightly better, but also a little bit similar, are the findings that refer to the sub-sector Transport, since the estimated CARGs for the three domestic markets are on a moderate level between 1.074% (Regional) and 1.153% (BSR), or 1.084% for the national markets, respectively – whereby again obviously through the increase of the geographical scope of the market, the CAGR increases, too. Therefore, it can be stated and concluded that for all these sub-sectors – namely: Aquaculture, Coastal & maritime tourism, Mineral resources, Renewable energy and Transport – the domestic markets show only a low or in some cases moderate future growth potential.

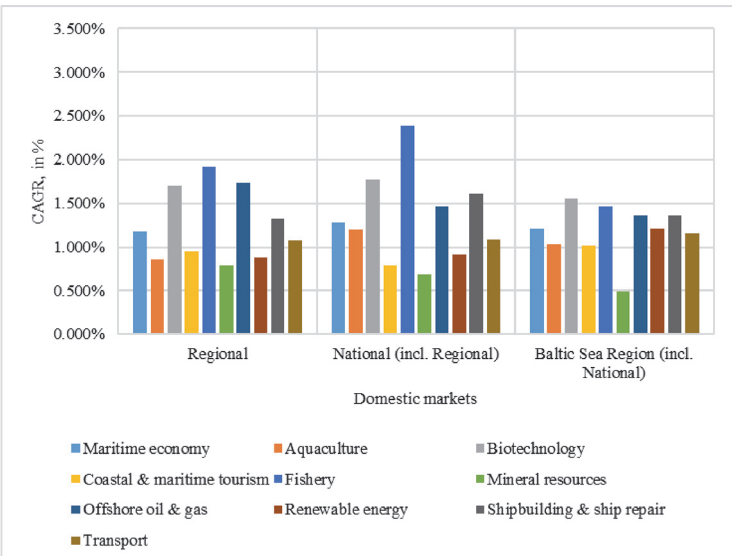

Figure 2. CAGR on Blue Economy sector level – domestic markets

All other four sub-sectors – namely: Biotechnology, Fishery, Offshore oil & gas, Shipbuilding & ship repair – exhibit greater future growth potentials on the domestic markets. For instance the average CAGR for Biotechnology firms on the basis of all three domestic markets is equal to 1.676% (Regional = 1.707%, National = 1.770%, BSR = 1.551%). Even greater is the future growth potential on the domestic markets that is related to the sub-sector Fishery, since the CARG for the regional markets is equal to 1.924%, for the national markets 2.384% – which is one of the highest CAGRs in the entire present study – and 1.457% for the BSR market. Also the Offshore oil & gas sector promises a sufficient growth potential in the next years on the domestic markets – Regional = 1.738%, National = 1.457% and BSR = 1.362% – whereby obviously through the increase of the geographical scope of the market, the CAGR decreases, too. On a similar attractive level are the predicted CARGs for the three domestic markets that occur in case of the sub-sector Shipbuilding & ship repair, with 1.324% on the regional, 1.611% on the national, and 1.354% on the BSR market(s).

International markets

The elaborated results for the international markets differentiated according to the five nations of the SBSR are summarised in Figure 3. According to Figure 3, from a holistic perspective (i.e. maritime economy from SBSR as a whole), among all continental markets the European market (1.332%) represents the most important one, since the highest CAGR is expected, which suggest even greater future growth potential than the different domestic markets. Furthermore, also the Asian market exhibits some relevance with an annual turnover growth rate of 0.981%. Vice versa, all other continental markets (Africa = 0.674%, Australia = 0.620, North America = 0.778% and South America = 0.758%) show a very low future growth potential. This might be seen as an indicator that overall there is very low demand on these international markets for products and services that are offered by maritime companies from SBSR. On the other hand, another explanation might be seen in the possibility that maritime companies from SBSR are not active enough on these international markets due to their general low degree of internationalisation. Lastly, the aggregated results of all international markets resulted in the achieved CARG worldwide, which is only about 0.955%. Hence, it can be concluded that generally the future potential of the maritime economy from SBSR on international markets is nearly moderate, but not very attractive. Furthermore, it can be stated that from a holistic perspective, especially the European market plays a crucial role in the future for maritime economy companies from SBSR.

As mentioned before, Swedish and especially German Blue Economy firms evaluate the future growth potential on domestic markets more pessimistic than companies from other SBSR countries. The same applies for the international markets (SE: Europe = 0.9%, Africa = 0.981%, Asia = 0.884%, Australia = 0%, North America = 0.397%, South America = 1.172%, Worldwide = 0.815%; DE: Europe = 0.862%, Africa = 0.232%, Asia = 0.475%, Australia = 0.232%, North America = 0.159%, South America = 0.080%, Worldwide = 0.441%). An exception is the market in South America for maritime economy companies from Sweden, since among all compared markets (incl. domestic markets) the highest growth potential is predicted for the South American market (1.172%) in case of Swedish firms. Nevertheless, this finding can be evaluated only as moderate. In addition, it can be derived that among all partial samples, Blue economy firms from Sweden exhibit the highest CAGR for the African market (0.981%). Against this, especially the Australian markets has no relevance for firms from Sweden (0%) and the resulting worldwide CAGR with 0.815% is also quite low. In case of the German firms, all CARGs on international markets are too low, whereby compared with the values that had been achieved on the domestic markets, it can be stated that the European market has a similar relevance (0.862%), which at the same time is the highest CARG of all international markets in case of German firms. In contrast to the Swedish companies, for German firms, the market in South America has no relevance due to a CAGR of 0.080%. Therefore, the resulting annual growth rate worldwide with 0.441% in case of German Blue Economy firms is insufficient.

Against this, the maritime economy firms from Denmark show high future potential among all international markets (Asia = 2.565%, Australia = 3.19%, North America = 1.645%, South America = 1.513%, Worldwide = 1.47%), whereby for the African market no data was received, and the CARG that refers to the European market (1.16%) can be evaluated as on a moderate level, similar as the other domestic markets. The CARGs for Asia, Australia, North America and South America by Danish firms, represent the highest growth potential on international markets in the next years among all SBSR countries, whereat also in the case of the worldwide CARG Danish companies are outperforming.

For both, Lithuanian (1.636%) and Polish (1.738%) firms, among all international markets, the European market is the most important one. Additionally, in case of maritime economy companies from Lithuania, also the Asian market (1.213%) has a moderate priority, as well as to a certain degree also the market in South America (0.965%), whereby in case of Polish companies, only the North American (0.965%) market has some additional relevance. Accordingly, it can be concluded that for Lithuanian firms, the business in African (0.906%), Australian (0.928%) and North American (0.671%) markets is not attractive. Even worse is the predicted future growth potential of Polish companies on the African (0.593%), Asian (0.658%), Australian (0.298%) and South American (0.331%) markets. The overall worldwide CAGR in case of Lithuanian companies (1.1%) can be assessed as moderate, whereby the aggregated worldwide annual growth rate in the course of Polish firms (0.905%) is too low.

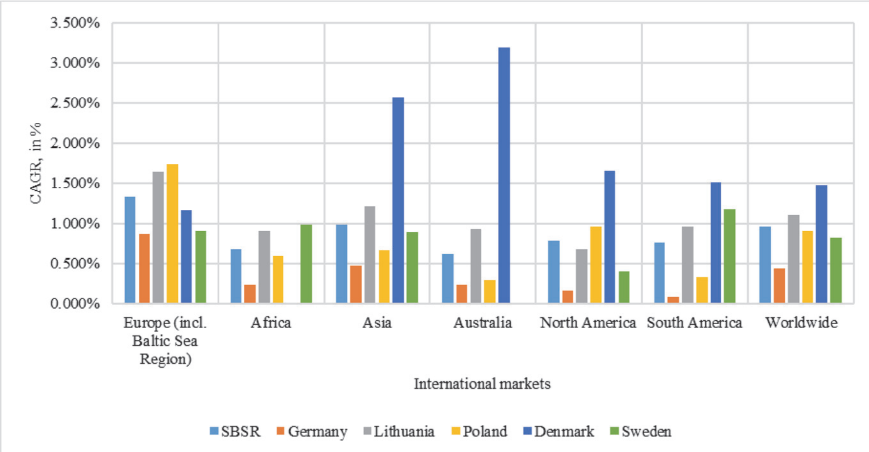

Figure 3. CAGR on national level – international markets

The results for the international markets differentiated according to the nine sub-sectors of the Blue Economy are summarised in Figure 4 below. According to Figure 4, it can be concluded that the importance of the international markets among the nine sub-sectors of the Blue Economy is quite heterogenic. For instance, for the maritime economy sub-sector Aquaculture from SBSR, international continental markets play no role (Africa, Asia, Australia, North America, South America = 0%), with a small exception in case of the European market (0.723%), which is also still less attractive. Accordingly, also the aggregated results in form of the worldwide CAGR cannot convince (0.273%) in case of the sub-sector Aquaculture. Similarities apply for the sub-sector Biotechnology, where international markets are once again unappealing (Africa = 0%, Asia = 0.199%, Australia = 0%, North America = 0.739%, South America = 0%). Single bright spot is the European market with a quite strong CAGR (1.629%), which is on a similar level as noticed on the domestic markets, and the highest score compared to all other sub-sectors. Nevertheless, the overall worldwide CARG of Biotechnology firms is with 0.616% too low. Quite similar are the findings in case of the Blue Economy sub-sector Fishery (Africa, Asia, Australia = 0%, North America = 0.495%, South America = 0%), whereby at least the CARG that belongs to the European market (0.981%) can be evaluated as more or less moderate. Nevertheless, in case of the sub-sector Fishery, the cumulated results that form the worldwide annual growth perspective (0.372%) are insufficient. Also for the sub-sector Mineral resources, international markets play completely no role (Europe, Africa, Asia, Australia, North America, South America, Worldwide = 0%). To the same group of "losers" also belongs the sub-sector Offshore oil & gas, since again, the achieved results suggest that there is no future potential for these sub-sector companies from SBSR on these respective international markets (Africa, Asia, Australia, North America, South America = 0%), whereat exception is made again in case of the European market with a positive result in terms of the CAGR (1.457%). Therefore, it is also not surprising that the resulting worldwide CAGR (0.425%) is also quite low in case of Offshore oil & gas companies from SBSR. Finally, it can be concluded that for all these sub-sectors (incl. Aquaculture, Biotechnology, Fishery, Mineral resources, Offshore oil & gas) domestic markets have a higher priority than international markets.

A little bit better is the picture in case of the maritime Transport sector, since the CAGR that refers to the European market is on a moderate level with 1.244% and in case of the Asian market (1.013%) more or less moderate. In case of all other international markets (incl. Africa = 0.826%, Australia = 0.174%, North America = 0.619%, South America = 0.868%), the predicted annual turnover growth rates are insufficient. This is also reflected by the received worldwide CARG (0.933%) in case of companies that belong to the maritime Transport sector.

In case of the sub-sector Coastal & maritime tourism, moderate demand is expected from the European (1.299%) and Asian (1.108%) market, whereby the revenue stream from North America is the highest among all included sub-sectors (1.676%). In contrast to this, the demand from the African (0.298%), Australian (0.787%) and South American 0.495%) market is very low. Nevertheless, the thereof resulting worldwide CARG in the frame of the sub-sector Coastal & maritime tourism with 1.077% is still moderate.

In comparison to all sub-sectors of the Blue Economy from SBSR, the highest future growth rates are visible through Renewable energy companies on African (1.457%) and Australian (1.645%) markets. Against this, the CAGR that refers to the Asian market (1.267%) can be assessed as moderate and in case of the North American market (1.077%) as still moderate. Vice versa, the European (0.787%) and South American (0.884%) market play a subordinate role in case of Renewable energy firms. However, the resulting worldwide future annual turnover growth rate (1.131%) of Renewable energy firms is also moderate.

Similarities apply for the sub-sector Shipbuilding & ship repair, where the highest CARGs on the European (1.694%) and Asian (1.414%) markets are noticeable in the entire sample differentiated according to the different Blue Economy sectors. Also in case of the Australian (1.05%) and South American (1.068%) markets, the future potential can still be evaluated as moderate, whereby it is a little bit surprising and sorrowful that the CARG for South America, which was achieved by Shipbuilding & ship repair companies, at the same time is also the highest among all other sub-sectors. Furthermore, the CARG for North America (0.981%) shows a tendency to a moderate level. Therefore, only the annual turnover growth rate that belongs to the African market (0.852%) can be assessed as a little bit too low. Accordingly, by taking all these detailed results into account, it is not surprising that the resulting worldwide average growth rate with 1.216% of the Shipbuilding & ship repair sector is the greatest in the whole sample.

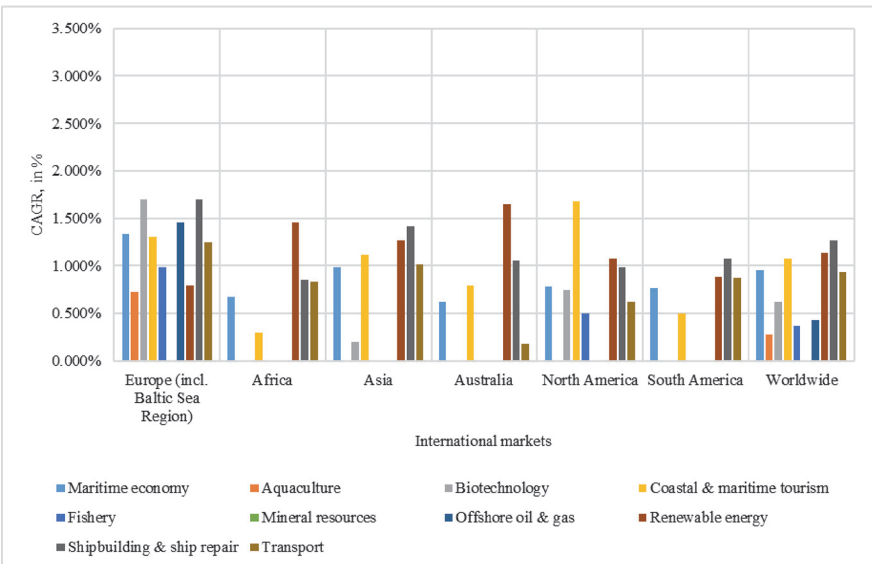

Figure 4. CAGR on Blue Economy sector level – international markets

4.2. Trends

In order to identify trends that have a potential influence on the future business of maritime economy companies from SBSR, in the underlying online survey, participants had been asked to evaluate the strength and the kind (i.e. positive or negative) of the impact from (1) Digitalisation, (2) European Guidelines for the development of the TEN-T and (3) International regulations that affect business of maritime industry and related stakeholders – particularly IMO Marpol Annex VI, BSR as Sulphur

Emission Control Area (SECA); Global Sulphur Cap; etc. These potential trends were chosen for the present study, since they are currently highly discussed in the research landscape on maritime industry (e.g. Henesey & Philipp, 2019; Madjidian *et al*., 2017; Meyer *et al*., 2020; Philipp *et al*., 2018, 2019b, 2019c & 2020). By doing so, a five item scale was given with "(-2) Very negative", "(-1) Rather negative", "(0) Neutral", "(+1) Rather positive" and "(+2) Very positive", whereby participants also had the option to choose "Not aware", which – of course – is excluded from the following analysis. The received data through the online survey – structured according to this Likert-scale – was processed through descriptive statistical analysis by using the arithmetic mean.

Once again, it should be noted that in the following, firstly, the received results are presented in relation to country differentiation/affiliation and secondly, in contrast to the differentiation of the different nine sub-sectors of the Blue Economy. Accordingly, through the aggregation of the received results of all five countries, the holistic perspective of the maritime economy from SBSR as a whole is gathered, which is equal to the aggregation of the received results of all investigated nine sub-sectors. Thus, on the one hand, the aggregation of the received results from national level, and on the other hand, the aggregation of received results from sub-sector level, form the study sample: maritime economy in SBSR – neglecting the circumstance that in the following in some cases only the SBSR or maritime economy alone is showcased.

The elaborated results in the frame of the trend analysis differentiated according to the five nations of the SBSR are summarised in Figure 5 below. According to Figure 5, from a holistic perspective, digitalisation has the highest importance and thus, is expected to have the strongest impact on the future business of Blue economy firms from SBSR with a resulting arithmetic mean of 0.969; compared with the other considered potential trends TEN-T (0.39) and SECA Regulation & Global Sulphur Cap (0.27). Furthermore, it should be noted that all three potential impacts show a positive sign, which indicates that all three trends are expected to have a positive impact on the future business of maritime economy companies from SBSR.

This finding is also noticeable on respective national level, where digitalisation generally is expected to have the greatest positive impacts on the future business (DE = 0.889, LT = 0.923, PL = 1.12, DK = 1, SE = 0.947). By comparing the other two trends (TEN-T and SECA Regulation & Global Sulphur Cap), it can be stated that German, Lithuanian and Polish companies predict that the TEN-T (DE = 0.286, LT = 0.538, PL = 0.571) will have a greater positive influence on their future business than SECA Regulation & Global Sulphur Cap (DE = 0.176, LT = 0.231, PL = 0.238). Vice versa, in case of maritime economy companies from Denmark and Sweden the impact of the trend in case of SECA Regulation & Global Sulphur Cap (DK = 0.409, SE = 0.368) is higher positively evaluated than the one that will be induced by the TEN-T (DK = 0.348, SE = 0.222). Nevertheless, also on individual national level, all potential trends are expected to have a positive impact on the future business.

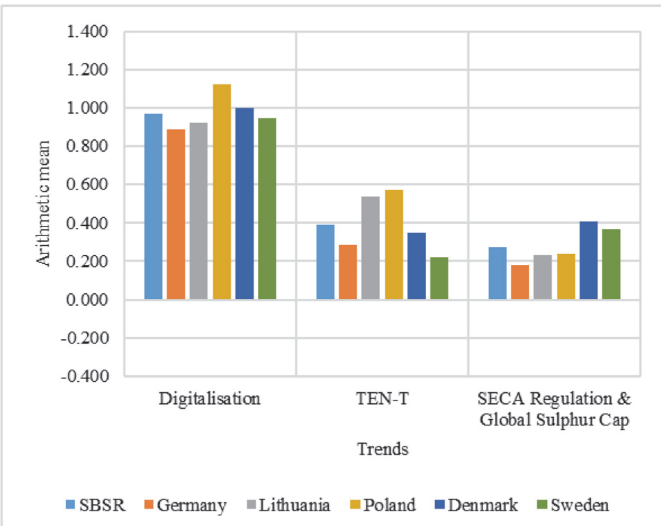

Figure 5. Trends on national level

The results in the frame of the trend analysis differentiated according to the nine sub-sectors of the Blue Economy are summarised in Figure 6. According to Figure 6, it can be derived that also digitalisation is expected to have among all nine sub-sectors of the Blue Economy in SBSR the greatest positive impact (Aquaculture = 1.25, Biotechnology = 0.833, Coastal & maritime tourism = 1.1, Fishery = 0.333, Mineral resources = 0.667, Offshore oil & gas = 1, Renewable energy = 0.667, Shipbuilding & ship repair = 0.879, Transport = 1.091), whereat the expected intensity varies. Only Offshore oil & gas companies predict that the TEN-T will have the same strong positive impact as digitalisation on their future business, whereby SECA Regulation & Global Sulphur Cap also is expected to a have a positive impact on future business activities (0.5), but not as strong as in case of digitalisation and TEN-T. Furthermore, firms from the Aquaculture sector claim that the TEN-T will have a stronger positive influence on their future business (0.429) than SECA Regulation & Global Sulphur Cap, where no impact is expected at all. In contrast to this, Biotechnology firms predict generally no relevance of the TEN-T and SECA Regulation & Global Sulphur Cap for their future business, neither directly nor indirectly. Coastal & maritime tourism firms see equal strong positive influences on their business that might emerge from the TEN-T and SECA Regulation & Global Sulphur Cap (both: 0.333). The results of the Fishery sector from the SBSR encapsulate a peculiarity, since the TEN-T is expected to have a negative influence on the future business (-0.167), whereby the arithmetic mean in case of SECA Regulation & Global Sulphur Cap implies that this trend seem to have no future relevance. A similar peculiarity is obvious in case of the sub-sector Mineral resources, since these firms predict that SECA Regulation & Global Sulphur Cap will have a negative impact on their future business (-0.333), but TEN-T a positive one (0.333) with the same intensity. Renewable energy firms evaluate the future business impacts coming from TEN-T (0.333) and SECA Regulation & Global Sulphur Cap (0.167) positive, but in case of the TEN-T a little bit stronger. In the course of Shipbuilding & ship repair companies, the influence of TEN-T (0.452) and SECA Regulation & Global Sulphur Cap (0.484) on the future business is expected to be positive and nearly equipollent. In contrast to this, the Transport sector predicts a stronger positive impact from the TEN-T (0.444) than from the SECA Regulation & Global Sulphur Cap (0.259).

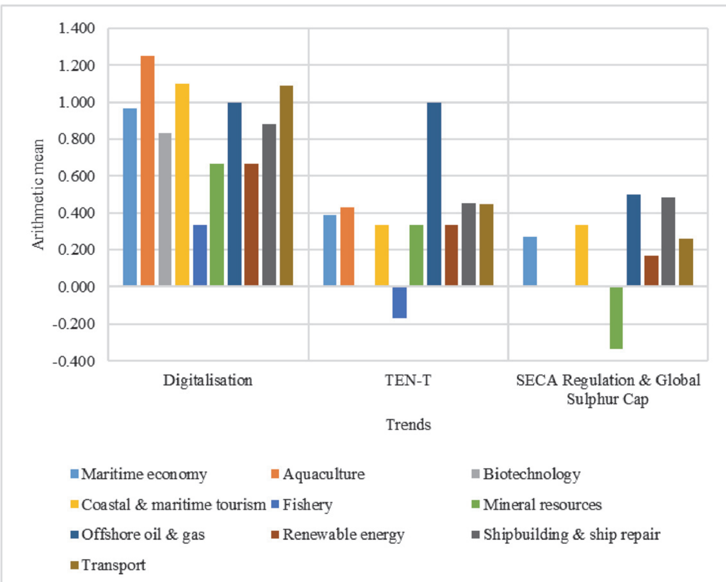

Figure 6. Trends on Blue Economy sector level

5. Discussion and conclusion

In this study, the future potential of the maritime economy in SBSR as well as trends that impact the future sustainable development of this blue sector were investigated. By taking all findings into account, it can be concluded that overall – from a holistic perspective on the maritime economy in SBSR – domestic markets and the European market are more important than all other international markets. In addition, generally, the worldwide CAGR of the entire Blue economy from SBSR is with 0.955% on a moderate level. Furthermore, the maritime economy firms from Germany and Sweden will face some disadvantages compared to companies from Lithuania, Poland and Denmark, since their expected future market potential is quite low, with exception of the South American market in case of Swedish firms. From a sector specific perspective, it can be determined that most of the sub-sectors show also low future growth potential. For instance, it can be concluded that for the sub-sectors Aquaculture, Coastal & maritime tourism, Mineral resources, Renewable energy as well as Transport, the domestic markets have only low or in some cases moderate future growth potentials. All other four sub-sectors – namely: Biotechnology, Fishery, Offshore oil & gas, Shipbuilding & ship repair – exhibit greater future growth potentials on the domestic markets. Moreover, it can be derived that for the sub-sectors Aquaculture, Biotechnology, Fishery, Mineral resources as well as Offshore oil & gas, domestic markets will have a higher priority than international markets. Thereby, especially the sub-sectors Aquaculture and Mineral resources will face some problems, since international markets seem to play a subordinate role for them, whereby the calculated CAGRs suggest that also on the domestic markets the future growth potential is quite low. Against this, Coastal & maritime tourism, Renewable energy and especially Shipbuilding & ship repair from SBSR show the greatest future growth potential in the context of international markets.

Concerning the internationalisation efforts, especially for companies from Germany and Sweden as well as at all in the case of the sub-sectors Aquaculture, Biotechnology, Fishery, Mineral resources as well as Offshore oil & gas urgent need for actions were identified in this study. Since also the future potential in case of the Transport sector cannot convince, this sub-sector must be also considered to this low performance group. Hence, in order to systematically foster Blue Growth in the SBSR, particularly these sub-sectors need to be supported.

However, since turnover growth rates over 20% (hi = 7) had been considered as outliers in this study, it can be concluded, that the conducted analysis of the future potential of the maritime economy in SBSR followed a more pessimistic perspective. The resulting advantage through this procedure can be seen in an increased probability that the findings are more closely related to realistic market conditions – i.e. increased reliability. On the other hand, the potential disadvantage could be seen in the circumstance that this measure could have had an impairing effect on the resulting and interpreted CARGs, which at the same time might be regarded as a potential methodological limitation of the present study. On the other hand, the results that refer to the two sub-sectors Mineral resources as well as Offshore oil & gas have only limited significance and validity, since both sub-sectors are underrepresented in the underlying sample of this study. Accordingly, this can be regarded as another methodological limitation that refers to the partial sample sizes of the sub-sectors Mineral resources as well as Offshore oil & gas.

Nevertheless, the overall findings underpin the urgent need of the initiated EU-project INTERMARE South Baltic that aims to support the maritime economy in the SBSR by the creation of a network of companies and stakeholders under the common brand “INTERMARE South Baltic”, which will be easily recognised in the region and in other European and global markets. Vice versa, it is in the future responsibility of project consortium and other stakeholders outside the project (i.e. investors, entrepreneurs, scientists, politicians, etc.) to adjust the future measures and activities in an appropriate way to overcome these identified grievances from this study. Through this, essential, crucial and necessary steps can be taken in order to ensure an effective promotion and sustainable growth of SMEs from the maritime economy in SBSR on international markets. This will most efficiently foster SMEs from the Blue Economy in SBSR in their efforts of internationalisation.

Hence, the present study contribute to regional development and policy issues through the identified and analysed trends and future growth potential of the maritime economy in SBSR. Future works should target to develop a common development strategy for the maritime industry of SBSR in order to reach a sustainable internationalisation of SMEs, since other competing regions and maritime clusters in Europe already implemented sustainability and marketing strategies. This present study delivers the well-needed essential input and further insights for these upcoming tasks. As an extra concluding remark, since in all investigated SBSR countries and among all Blue Economy sub-sectors, digitalisation was detected as the most important mega trend that is expected to have the greatest positive impact on the future growth potential, this aspect should be taken into account in the frame of related future studies.

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Publication II

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Small and Medium-Sized Seaports on the Digital Track: Tracing Digitalisation Across the South Baltic Region by Innovative Auditing Procedures

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Abstract. Digitalisation and the steady increasing wide range of related novel technologies are currently and in the next years of high topicality in policy, business and research landscape. This rising interest evolved over the last decade and resulted into different use cases of these data-enabled technologies in distinct industries like manufacturing, IT and logistics. Thereby, digitalisation is often regarded as the saviour for managing the challenges in further growing globalisation, competition and environmental issues as well as customer-oriented supply chain focus.

In order to keep pace with the fast changing market environment and customer needs, especially small and medium-sized ports have to take action now, since their bigger counterparts are already heavily investing in digital technologies, as they have recognised the added value. First empirical results from the EU-project Connect2SmallPorts have shown that small ports in the South Baltic Sea Region have a common and high interest in digitalisation, but often do not know about the already existing wide range of digital technologies and the arising benefits. Accordingly, in accordance with the INTERREG project Connect2SmallPorts, the present research aims to develop a digital auditing tool in order to discover the digital status of small and medium-sized seaports. The research builds upon on an extensive literature review and further utilises innovative approaches and combines theoretical concepts as well as project-gathered practical insights. The research results will showcase a target-group-oriented (here: small and medium-sized ports) digital auditing tool that will be applied in the further course of the EU-project Connect2SmallPorts.

Keywords: Small and medium-sized seaports · Digitalisation · Auditing · Key Performance Indicators

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1 Introduction

In recent discourses, digital technologies, such as safe and secure distributed databases – blockchain – 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 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 paper develops the so-called digital auditing procedures and digital auditing tool that will be applied in the involved regional ports. By doing this, researchers 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 paper yields both theoretical and practical contributions, where the affected actors themselves can test and utilise the developed tool.

The paper is structured as follow: In the second chapter, the needed theoretical background is drawn for the theory and target-oriented choice of direction for the development of the digital auditing tool. Afterwards, the used methodology is set out. Subsequently, the results from the conducted literature review are highlighted and the developed concept is described. The paper rounds up with a discussion and conclusion.

2 Theoretical Background

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. [9, 10], 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 [11]. 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. [12–16]). 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 [7, 17–20].

Furthermore, since the aim of the present study 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 [7], 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 [7]. 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. [16] – 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. [21], 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 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.

3 Methodology

The theory-based and practical findings demonstrated in this study have been originally collected and produced in the course of the ongoing 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 Southern Baltic Sea Region.

The majority of the presented results of this study base on 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 partners. The received data (qualitative expert interviews) was anonymized. Accordingly, during expert interviews, it was indicated that the provided data was always treated confidentially and for further purposes aggregated anonymously in order to make the data usable for research and scientific purposes only. This information was given in order to be in line and to show compliance with the current General Data Protection Regulation (EU) 2016/679 (GDPR). In addition, the applicability of the received and elaborated research findings (here: 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.

Accordingly, the study involve work with only human respondents and was conducted primarily in BSR. Hence, the authors considered ethical principles that ensured all data were analysed and treated according the principles of good scientific practice. Therefore, the researchers paid careful attention to honesty in data reporting, results, methods, procedures and during the publication process in general. Experts were volunteers and their answers were analysed anonymously. Moreover, it may be noted that respective respondent identity was protected in all phases of the research.

4 Results

Due to the lack of target-group-oriented theories and concepts (cf. chapter 2), 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 [22], 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 [23]. 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 [24].

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 [25], Industry 4.0 Readiness Index from the consultancy company Roland Berger [26] and the DiGiX (Digitisation Index) from BBVA Research [27]. 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 [24], 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 [22] 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 [28] 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 Table 1. Since the developed concept at the same time represents a digital readiness index for ports, we call it DRIP.

Table 1. Digital auditing tool for ports – DRIP.

Dimension	Weight	No.	Indicator (* = PPI)	Source
Management	20%	1.	Digitalisation strategy (incl. Governance, Standards, Cultural Guidelines, Progress Indicators, etc.)	[23, 24, 29–39]
		2.	Digital business model	[22, 32, 35, 38–41]
		3.	Investments in digitalisation	[22, 24, 29, 30, 35, 42]
		4.	Innovation cooperation	[22, 23, 31, 34, 35, 37]
Human capital	20%	5.	IT knowledge & skills (Education)*	[16, 22, 30–33, 35, 37, 38, 43, 44]
		6.	IT capabilities*	[16, 24, 29, 30, 35, 37, 45, 46]
		7.	IT training & education opportunities*	[16, 23, 30, 33, 35–37, 47]
Functionality (IT)	25%	8.	Integrated communications infrastructure*	[16, 21, 35, 37–39]
		9.	Information regarding status of shipment*	[21, 46, 48]
		10.	On-time of information*	[21, 39, 46, 49]
		11.	Operating system*	[16, 21, 35, 38]
		12.	Processes*	[16, 21, 32, 35, 37–39, 47]
		13.	Security	[24, 29, 30, 32, 35, 37, 39, 42, 49]
Technology	30%	14.	Smart ERP system	[16, 22, 39, 42, 43, 47, 49, 50]
		15.	Smart WMS system	[22, 35, 42, 47]
		16.	Smart PCS system (incl. electronic SCM system)	[35, 36, 42–44, 47, 49]
		17.	Web-based communication platform	[16, 22, 35]
		18.	Mobile data access for employees	[16, 22, 24, 29, 30, 35, 42, 43]
		19.	Mobile data access for customers	[16, 22, 24, 29, 35, 42]

(*continued*)

Table 1. (*continued*)

Dimension	Weight	No.	Indicator (* = PPI)	Source
		20.	IoT (incl. Machine-to-Machine-Communication)	[22, 24, 29, 31, 35, 36, 39, 49–51]
		21.	Cloud computing (SaaS, PaaS, IaaS)	[22–24, 29, 31, 35, 38, 39, 43, 44, 47, 49–51]
		22.	Localisation technologies (GPS, RFID, etc.)	[22, 24, 29, 32, 35, 40, 43]
		23.	Sensors (Humidity, Temperature, etc.)	[22, 24, 29, 32, 35, 37, 39, 40, 47, 49–51]
		24.	Big data & predictive analytics (e.g. for Maintenance, etc.)	[22, 24, 29, 31, 32, 34–39, 49–51]
		25.	Blockchain (incl. Smart Contracts)	[22, 39]
		26.	Artificial Intelligence (AI)	[22, 37, 39, 51]
		27.	Robotics	[22, 47, 51]
		28.	Drones (Air, Land, Water)	[22, 36]
		29.	Autonomous solutions (Terminals, Cranes, Vehicles) – CPS (Cyber-Physical Systems)	[22, 35, 37, 39, 51]
		30.	Digital twinning, augmented & virtual reality (incl. Simulation)	[22, 31, 32, 34–39, 47, 49–51]
Information	5%	31.	Personal network	[22]
		32.	Printed media	[22]
		33.	Internet	[22]
		34.	Social media resources	[22]
		35.	Fairs	
		36.	Conferences	
		37.	Associations (e.g. Consultancy, etc.)	[22]
		38.	Scientific institutions	[22]

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 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 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 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 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 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 potential future incorporation of PPIs that target to measure the operational performance of small ports, 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 September to December 2019. 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.

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Digital readiness index assessment towards smart port development

Robert Philipp[1,2]

Abstract
Digital technologies receive more and more attention in the maritime transport sector. Large ports such as Rotterdam or Antwerp are already heavily investing in digital databased technologies and thus, continue to rely on a sustainable expansion of these advanced technologies that promise security, process optimization and sustainability. Conversely, especially smaller ports have no or limited knowledge on what Industry 4.0, IoT and Blockchain are and what potentials they may have. Nevertheless, without the inclusion of small and medium-sized ports, the innovative idea towards a smart port development stays unachievable. Related to this, there exist a lack of concepts and models for measuring the digital performance of ports. Without such tools, it is impossible to audit the digital status of ports and to derive a concrete strategic roadmap for the digital transformation of ports. Accordingly, in this study, the research questions will be investigated, how the digital performance of ports can be assessed, and which strategic recommendations can be derived for ports regarding a sustainable development towards a smart port. Building upon the received qualitative data that were gathered through an online survey and IT based expert interviews, a digital readiness index for ports is applied in case of five selected seaports. The results will show that building upon the benchmarking and indexing of the ports, the current strategic positioning of the ports becomes apparent. Through this, the respective strategic recommendations for a sustainable development towards a smart port can be derived in accordance to each port classification.

Keywords Digitalisation · Smart Port · Port Performance Measurement · Port Performance Indicators · Digital Readiness Index · Maturity Model

1 Introduction

Since recent years, the interest in digital technologies and their progress in various industrial and service sectors increases. Due to the promising value proposition, the growing cross-sectoral distribution and the value creation potential of digital technologies, they also receive more and more recognition in the maritime industrial and transport sector (Philipp et al. 2020a, 2018). In the European context, especially large ports—the so-called core ports of the "Trans-European Transport Network" (TEN-T)—such as Rotterdam or Antwerp are already familiar with digital databased technologies like Blockchain or Internet of Things (IoT) and thus, continue to rely on a sustainable expansion of these advanced technologies that promise security, process optimization and sustainability. They are developing rapidly and merge into huge digital networks and platforms. By doing so, they connect and converge physical and digital worlds (i.e. machines, devices and humans). The main goal of such novel digital technologies is to optimize economic performance and energy demand, to reduce the consumption of resources and waste and to better qualify the service portfolio. Indeed, seaports rely on large transport and logistics companies when it comes to the development and implementation of innovative technology applications. Since major transport companies like Maersk are already heavily investing in digital technologies that are regarded as the enablers for the digital transformation in the context of Industry and Logistics 4.0, it is important that also ports—including in particular small and medium-sized ports—take the opportunity to apply these novel technological solutions in order to integrate themselves in a sustain-

Availability of data and material R. Philipp collected and analysed the used and presented primary data that was gathered in the frame of the project "Connect2SmallPorts", which is part-financed by the European Regional Development Fund (INTERREG VA South Baltic programme).

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able way into global supply chains. Otherwise, in the long-term, this will result in uncatchable competitive disadvantages. Accordingly, dealing with new digital technologies is crucial for both, large core ports and small and medium-sized ports (Philipp et al. 2018).

Especially, when it comes to the novel visionary idea of a smart port development, which currently receives a growing attention in practice and research landscape, the investigation with digitalisation and related novel technologies becomes more and more important. The idea of a smart port development is associated with an innovative endeavour where the focus is centred on improving the competitiveness of the port and facilitating entrepreneurial collaboration between different port stakeholders to achieve horizontal and vertical integration of supply chains (Douaioui et al. 2018). Hence, in such a scenario the port will be completely connected via a communications network and fully integrated with its environment (i.e. all stakeholders of the industry) as well as other ports and logistics actors around the globe. Accordingly, without the inclusion of small and medium-sized ports, this innovative idea stays unachievable. However, so far, this idea of a smart port is still a vision. Nevertheless, it is expected that especially the usage and implementation of the newly arisen digital technologies will contribute substantial to the development towards a smart ports.

Yet, especially smaller ports have no or limited knowledge on what Industry 4.0, IoT and Blockchain are and what potentials they may bring. Hence, 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 (Philipp et al. 2018). Next to this, in research and practice there exist a lack of concepts and models for measuring the digital performance of ports. Without such tools, it is impossible to audit the digital status of ports and to derive a concrete strategic roadmap for the digital transformation towards a sustainable smart port development (Philipp et al. 2020b).

In order to close these research gaps, this present study aims to apply a tool to assess the digital readiness of ports, and building upon this to derive a concrete strategic graduation that sets up the roadmap for the digital transformation towards a sustainable smart port development. Accordingly, in the framework of this study, the research questions will be investigated, how the digital performance of ports—regardless their size and cargo preference—can be assessed, and in a subsequent step, which strategic recommendations can be derived for ports regarding a sustainable development towards a smart port; or with other words: how to conceptualise the roadmap for the digital transformation of ports towards a smart port development?

The research was conducted in the frame of the still ongoing EU-project "Connect2SmallPorts", which is implemented in the cross-border cooperation platform INTERREG South Baltic Programme 2014–2020. 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 South Baltic Sea Region.

The paper is structured as follow: In the second chapter, the needed theoretical background is drawn by referring to "Port Performance Measurement", "Digital and Industry 4.0 Readiness Indexes and Maturity Models" and the aspired vision of a "Smart Port". Afterwards, the used method is set out. Subsequently, the results are highlighted, which is followed by a discussion regarding the developed model. The paper rounds up with a conclusion.

2 Theory

2.1 Port performance measurement

Port performance measurement (PPM) is widely accepted and performed in practice and research landscape. Principally, PPM concepts incorporate so-called Key Performance Indicators (KPIs), whereby due to their defined target-oriented purpose these KPIs are often labelled as Port Performance Indicators (PPIs) (e.g. de Langen et al. 2007; Talley 1994). One of the oldest, but most common frameworks for PPM is the one from the "United Nation Conference on Trade and Development" (UNCTAD) from 1976 (UNCTAD 1976), which is often concerned as the origin source in the course of newly developed PPI concepts. However, over a half of century most PPM concepts had been developed in order to measure especially the performance of container ports and container transport logistics (CTL) (e.g. Tongzon 1995; Talley 2006; Cullinane et al. 2005; Wang et al. 2003; etc.). Therefore, it can be noted that past research efforts focalised mainly on operative performance measurement in larger ports, who handle containers (Twenty-foot Equivalent Unit—TEU) as primary cargo type—that specifically in the European context are often associated with core ports in the sense of the TEN-T (Philipp et al. 2018).

Due to the arising interests in digitalisation, recent PPM concepts exhibit novel indicators like IT system, Databases, Networks, Integrated EDI for communication, Integrated IT to share data, etc. (Ha et al. 2019), but still exclusively had been elaborated and applied for container ports. Next to this target group limitation, there exist no PPI framework that was created for the purpose to measure the digital performance of ports (Philipp et al. 2020b). Accordingly, among other things, the existing PPM concepts in theory and practice do not refer to the wide range of innovative technologies that nowadays are regarded as the enablers for the digital transformation towards a smart port development (ibid.).

2.2 Digital and industry 4.0 readiness indexes and maturity models

In order to overcome the existing research gap of missing digital performance measurement instruments for ports, the big variety of developed digitalisation and Industry 4.0 readiness indexes and maturity models in recent years represents a promising research trend and suitable reference point. Thereby, Industry 4.0—the forth-industrial revolution—is the allegory of the digitalisation idea in the industrial and in particular manufacturing sector, and thus, is regarded as the digital transformation process of the industry, which becomes enabled and driven by the fast technology development (Horvat et al. 2018; Rajnai and Kocsis 2018). Digital and Industry 4.0 readiness indexes are well established on macro level, where they are applied to measure and compare the digital performance of different nations—for instance: Networked Readiness Index (NRI) from the World Economic Forum (2016), Industry 4.0 Readiness Index from the consultancy company Roland Berger (2020), Digitisation Index (DiGiX) from BBVA Research (n.d.). In contrast to this, of particular interest are especially the added numerous digital and Industry 4.0 readiness indexes and maturity models that have been developed during the last years for analysing and measuring the digital performance and Industry 4.0 readiness of companies (micro level). According to Rajnai and Kocsis (2018), digital and "Industry 4.0 readiness index assessments, and maturity models can support the management at benchmarking, and setting up a roadmap for the digital transformation of their company" by auditing the current digitalisation status of benchmarked firms. Hence, transferred to the port sector, the question emerges, why there is a lack of applied digitalisation/Industry 4.0 readiness index or maturity models, respectively, in order to set up the roadmap for the digital transformation of ports towards smart port development.

2.3 Smart port

The term smart port currently receives a growing attention in practice and different research studies. The idea of a smart port development is associated with an innovative endeavour where the focus is centred on improving the competitiveness of the port and facilitating entrepreneurial collaboration between different port stakeholders to achieve horizontal and vertical integration of supply chains (Douaioui et al. 2018). Building upon the findings from Yang et al. (2018), a smart port may be defined as a fully automated port where all devices are connected via IoT. Furthermore, a network of smart sensors and actuators, wireless devices as well as data centres make up the key infrastructure of the smart port, which allows the port operators or authorities, respectively, to provide more efficiently traditional and new services, whereby the major drivers in the smart port development are productivity and efficiency increases. Hence, various different technological applications are used to gather the needed data in order to enable the digital transformation towards a smart port development (ibid.). According to the Whitepaper from Gardeitchik et al. (2017) as well as smart port value creation model from Deloitte (2017) based on Porter's Value Chain Analysis (Porter 1985), the development of ports towards a smart port takes place in five stages:

- Stage 0: where the port has no automation at all,
- Stage 1: includes individual automation,
- Stage 2: where all port-involved stakeholders aim to integrate their systems to achieve better communication,
- Stage 3: the port and the hinterland players are connected through one single digital environment,
- Stage 4: smart port stage, connects each port with its environment and all ports globally with each other.

3 Method

Generally, most of the digital and Industry 4.0 readiness indexes and maturity models on micro level that had been introduced in theory and practice target to evaluate the performance of manufacturing firms, which is deeply rooted in the fact that they are the main target group in the context of Industry 4.0. In particular, the overall logistics sector is relatively unaffected by digital and Industry 4.0 readiness indexes and maturity models. Thus, Decker and Blaschczok (2018) claimed in their study that they had been the first, who elaborated a digital readiness analysis in the logistics sector—in detail: digital readiness index for Logistics Service Providers (LSPs). The research from Philipp et al. (2020b) confirmed this. Furthermore, they proposed on a theoretical basis a digital readiness index for ports in the frame of their literature review article, by what the identified and related research gap of missing digital performance instruments for ports was closed. This digital readiness index for ports is called DRIP and was developed on the basis of 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 plus practical findings that had been elaborated in the course of the EU-project Connect2SmallPorts. Accordingly, it is the first of its kind and allows to audit the digital performance of ports, e.g. in the frame of a potential self-assessment or benchmarking. Since, so far, the developed DRIP by Philipp et al. (2020b) was not applied and tested, it was used in the course of

Table 1 Digital Auditing Tool for Ports—DRIP (based on: Philipp et al. 2020b)

Dimension	Weight (%)	No	Indicator	Scale applied
Management	20	1	Digitalisation Strategy (incl. Governance, Standards, Cultural Guidelines, Progress Indicators, etc.)	Implementation status: 1) Not existing, 2) Pilot initiatives are planned, 3) In development phase, 4) Formulated and defined, 5) Is in implementation phase, 6) Is implemented
		2	Digital Business Model	
		3	Innovation Cooperation	
		4	Investments in Digitalisation	Share of digital investments (x), proportion of employees with an IT educational background (x): 1) $x \leq 10\%$, 2) $10\% < x \leq 20\%$, 3) $20\% < x \leq 30\%$, 4) $30\% < x \leq 40\%$, 5) $40\% < x \leq 50\%$, 6) $x > 50\%$
Human Capital	20	5	IT Knowledge & Skills (Education)*	
		6	IT Capabilities*	Level of capabilities, scope of training, adequacy of integrated communications, accuracy of information regarding status of shipment, provision of on-time of information, compatibility of operating system, degree of process adaptability in meeting customer requirements, degree of IT security: 1) Very bad, 2) Bad, 3) Rather bad, 4) Rather good, 5) Good, 6) Very good
		7	IT Training & Education Opportunities*	
Functionality (IT)	25	8	Integrated Communications Infrastructure*	
		9	Information regarding Status of Shipment*	
		10	On-time of Information*	
		11	Operating System*	
		12	Processes*	
		13	Security	
Technology	30	14	Smart ERP System	Degree of usage: 1) Technology/System not known, 2) No use case available, 3) Usage not planned, 4) Usage is planned, 5) In specific projects already implemented, 6) Comprehensive usage
		15	Smart WMS System	
		16	Smart PCS System (incl. Electronic SCM System)	
		17	Web-based Communication Platform	
		18	Mobile Data Access for Employees	
		19	Mobile Data Access for Customers	
		20	IoT (incl. Machine-to-Machine-Communication)	
		21	Cloud Computing (SaaS, PaaS, IaaS)	
		22	Localisation Technologies (GPS, RFID, etc.)	
		23	Sensors (Humidity, Temperature, etc.)	
		24	Big Data & Predictive Analytics (e.g. for Maintenance, etc.)	
		25	Blockchain (incl. Smart Contracts)	
		26	Artificial Intelligence (AI)	
		27	Robotics	
		28	Drones (Air, Land, Water)	
		29	Autonomous Solutions (Terminals, Cranes, Vehicles)—CPS (Cyber-Physical Systems)	
		30	Digital Twinning, Augmented & Virtual Reality (incl. Simulation)	
Information	5	31	Personal Network	Degree of information procurement: 1) Very low, 2) Low, 3) Rather low, 4) Rather high, 5) High, 6) Very high
		32	Printed Media	
		33	Internet	
		34	Social Media Resources	
		35	Fairs	
		36	Conferences	
		37	Associations (e.g. Consultancy, etc.)	
		38	Scientific Institutions	

* PPI

the present study. As shown in Table 1, the DRIP consists of five dimensions and 38 related indicators, whereby some of them represent PPIs. As mentioned by Philipp et al. (2020b), the indicated weighting factors in the DRIP model represent the importance of each dimension, which had been determined during expert interviews with project experts, whereby all 38 indicators are equally weighted in each dimension.

The following assessment presented in this paper bases on primary data analysis according to the received qualitative data.[1] The preceding empirical data collection activities for the present study were conducted between the 01st of December 2019 and 26th of January 2020, which represents a total data collection duration of 8 weeks. Since the digital auditing procedures took place in the setting of the still ongoing EU-project Connect2SmallPorts, which is part-financed by the European Regional Development Fund (INTERREG VA South Baltic programme), the main target group of this current study was also defined by small and medium-sized seaports of the South Baltic Sea Region (SBSR)—i.e. eligible catchment area of the INTERREG VA South Baltic programme. Thereby, medium-sized seaports are associated with comprehensive ports in the sense of the TEN-T, whereby small-sized ports do not belong to the TEN-T. Nevertheless, from empirical data collection activities, large seaports (i.e. core ports in the sense of the TEN-T) were not precluded, which enables in the further discourse of this paper the comparison with a best practice example as well as allows to prove the applicability and application friendliness of the investigated and applied DRIP—regardless of port size and cargo preference. Accordingly, due to the underlying EU-project Connect2SmallPorts that is implemented in the INTERREG VA South Baltic programme, the geographical scope of data collections activities mainly focused on the adjacent SBSR countries (namely: Germany, Lithuania, Poland, Denmark and Sweden). Nevertheless, the geographical scope of data collections activities was not limited to this region, which resulted in the frame of the present study into the incorporation of one Spanish port: Valencia. The reason for the inclusion of Valencia seaport can be seen in the fact that this core port according to the TEN-T shows the highest digital readiness among all ports, who participated in the online survey during the abovementioned study period. Moreover, since the usage of the DRIP model enables a benchmarking of ports, Valencia seaport was selected as the best-practice example in the course of the following analysis—i.e. due to its forerunner position in case of digitalisation.[2]

Therefore, the empirical data collection was at the beginning exclusively online-based, whereby the invitation to the online survey "Digital Auditing in Small Ports" reached the target group via E-Mails, which was ensured by the author of the present study. Accordingly, the following key advantages could be perceived through the online-based data collection: (1) ensuring that the questionnaire was carried out anonymously, (2) exclusion of influencing the respondents due to the survey situation, and (3) facilitation of respondents' time-based flexibility (Döring and Bortz 2016; Diekmann 2007; O'Leary 2017; Schnell et al. 2004). Vice versa, possible disadvantages of an online-based survey could be reduced or largely ruled out, since, for example, in order to prevent misuse in the form of multiple participation, the inclusion of cookies was conducted (Schnell et al. 2004), and comprehension problems—which can be discussed or clarified in an oral or telephone survey—could be limited or eliminated, as the topic and its essential contents were explained on the first page of the online survey. Against this background, it can be assumed that the ports, who participated in the online survey, are familiar with the topic (Philipp et al. 2019a).

Next to this, the participants of the online survey were informed on the first page of the online survey about the topic, aim and purpose of the survey and the EU-project Connect2SmallPorts as well as the subsequent data processing activities. Moreover, port representatives had been informed that participation in the survey is voluntary. At the end, these and further given information resulted in the option for the potential participants to agree on the indicated consent form and provided information, or not. All these information and explanations as well as the declaration of consent were showcased and implemented in order to be in line and to show compliance with the EU data protection regulation (ibid.).

However, in order to measure the digital performance of ports and thus, to demonstrate the applicability and application friendliness of the investigated and used DRIP model, as well as in a supplementary step, to assess the strategic graduation towards a smart port development, an evidence-based approach has been chosen and applied in the present study. Hence, by taking into account the indicated research objectives, the cases of five European seaports had been selected for the present study. Thus, these selected cases of five European seaports were compared in the following ac-

[1] Only in case of the two indicators "Investments in Digitalisation" and "IT Knowledge & Skills (Education)" also quantitative data was gathered. Accordingly, the majority (36 from 38 indicators) of elaborated data represents qualitative data.

[2] According to the respective figures from 2018, Valencia was worldwide on the 29th place in the container segment (Lloyd 2019). This once more highlights the sustainability of using Valencia seaport as a best-practice example for small and medium-sized ports in the current study.

cording to Yin (2017). To ensure this and highlight the particularity and complexity of the single case evidences (Stake 1995), further IT-based structured and semi-structured expert interviews had been conducted with top-level managers from selected five seaports, which mainly had been carried out in January 2020. The interviews lasted about 1 h. The results from the online survey, together with the findings from the expert interviews ensured to gain profound insights on the current digitalisation status of the investigated ports. Thereby, especially the expert interviews uncovered the backgrounds and reasons for the indicated answered to the closed-ended questions in the online survey. However, more important was—in a supplementary step of the expert interviews—validation and subsequent verification of the strategic graduation model towards smart port development, which was developed and proposed by the author of the present study. Accordingly, interviews were recorded and transcribed. Hence, indicated recommendations and suggestions for improvements regarding proposed model were taken into account. Finally, these activities in the frame of the interview analysis according to Kvale (2008) and Miles and Huberman (1984) led to the presented strategic graduation model towards smart port development.

Next to the abovementioned reason for the inclusion of Valencia seaport as a best practice example in the frame of the benchmarking, the other four seaports (namely: Klaipeda (LT), Karlskrona (SE), Wismar and Stralsund (DE)) had been selected for the present study out of 33 audited ports[3], since they had been chosen by the Connect2SmallPorts project as so-called pilot cases. Furthermore, the author is presenting these selected case studies—that have been evaluated on digital readiness by applying the DRIP—with a specific focus on promoting of the developed strategic graduation model towards smart port development.

4 Results

In line with the DRIP matrix presented in Table 1, the following assessment of the seaports Valencia (ES), Klaipeda (LT), Karlskrona (SE), Wismar and Stralsund (DE) took place.

Thereby, the PPI "IT Capabilities" in the dimension "Human Capital" was further differentiated into the subindicators "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". Accordingly, the respective findings concerning the PPI "IT Capabilities", which are highlighted in Table 2 (here: aggregated results through the usage of the arithmetic mean), are showcased in detail in the following Table 3.

Building upon the maturity models from Gill and VanBoskirk (2016) as well as Gardeitchik et al. (2017), and the smart port value creation model from Deloitte (2017) based on Porter's Value Chain Analysis (Porter 1985) as well as results from the conducted expert interviews, the author of the present study proposes the following strategic graduation model towards smart port development in Table 4.

According to Table 2, the best performing port in the study is the Mediterranean seaport Valencia, since the digital readiness index assessment (DRIP) delivered the highest score or index with 5.195. Hence, Valencia seaport shows the highest digital readiness among all investigated cases. Therefore, in the present study, the Spanish seaport is the best-practice example in the course of the benchmarking. Valencia is classified as a core port according to the analogy of the TEN-T and thus, can be regarded as a large port. In 2019, the total cargo throughput amounted to ca. 80,000,000 t, whereby the focus lies on container handling/traffic with about 77%. In the same year, about 1,141,000 passengers passed through the seaport. Regarding the results per dimension according to Table 2 and 3, it can be noted that potential for improvements is observable in case of "Human Capital" (4.905) and "Technology" (4.941). Therefore, in order to become a small port, it can be recommended to strategically foster actions in these two areas. Vice versa, the digital performances regarding the dimensions "Management" (5.5) and "Functionality (IT)" (5.5) are almost on a very high level. According to Table 4, the port of Valencia with a DRIP score of 5.195 can be classified in this study as a "Developer port".

The seaport of Klaipeda ranks on the second place in this study (cf. Table 2), resulting from a DRIP score of 4.871. The Lithuanian port, which is located in the BSR, is also classified according to the TEN-T as a core port. In 2019, the total cargo throughput was about 48,000,000 t. The port of Klaipeda is a typical multi-purpose port, since about 20% of the total freight is attributable to "Liquid bulk goods", 35% to "Dry bulk goods", 18% to "Containers", 11% to "Ro-Ro mobile self-propelled units" and about 16% to "Others, not specified cargo". Moreover, in 2019 ca. 68,000 passengers transited the seaport. By taking into account the results per dimension from Table 2, it can be stated that concerning the dimension "Management" and to a certain extend also in case of the dimension "Technology", the seaport of Klaipeda is on a similar

[3] 33 ports have been audited, which complies with the set target indicator 30+ indexed ports in the EU-project Connect2SmallPorts. Nevertheless, the online survey will be open and regularly updated during and beyond project lifetime until the end of the year 2026. Thus, access to the questionnaire is granted for interested port representatives via the following link: https://ww2.unipark.de/uc/Connect2SmallPorts-DRIP/.

Table 2 Digital Readiness Index Assessment

Dimension	Weight	Indicator	Valencia	Klaipeda	Karlskrona	Wismar	Stralsund
Management	20%	Digitalisation Strategy	6	6	1	3	2
		Digital Business Model	6	6	2	2	2
		Innovation Cooperation	6	5	2	2	2
		Investments in Digitalisation	4	5	1	2	2
Human Capital	20%	IT Knowledge & Skills*	5	5	2	1	2
		IT Capabilities*	4.714	4.286	3.286	3.714	5.000
		IT Training & Education Opportunities*	5	4	4	4	5
Functionality (IT)	25%	Integrated Communications Infrastructure*	6	5	3	3	5
		Information regarding Status of Shipment*	6	5	3	4	5
		On-time of Information*	5	5	3	4	6
		Operating System*	5	4	4	5	5
		Processes*	5	6	3	4	4
		Security	6	4	4	4	5
Technology	30%	Smart ERP System	5	5	3	5	4
		Smart WMS System	5	5	3	5	4
		Smart PCS System	6	6	4	5	3
		Web-based Communication Platform	6	6	5	5	3
		Mobile Data Access for Employees	6	6	5	5	4
		Mobile Data Access for Customers	6	5	4	5	3
		IoT (incl. M2M-Communication)	5	5	4	4	3
		Cloud Computing	5	4	4	5	3
		Localisation Technologies	5	6	4	4	4
		Sensors	6	5	3	4	4
		Big Data & Predictive Analytics	5	4	3	3	4
		Blockchain	4	4	4	4	3
		Artificial Intelligence	4	4	4	4	3
		Robotics	4	5	3	4	3
		Drones	4	4	4	4	4
		Autonomous Solutions—CPS	4	5	3	4	3
		Digital Twinning, Augmented & Virtual Reality	4	4	4	4	3
Information	5%	Personal Network	4	4	4	4	5
		Printed Media	5	5	5	3	5
		Internet	6	5	5	4	6
		Social Media Resources	6	4	5	3	4
		Fairs	5	4	3	3	6
		Conferences	5	4	4	4	6
		Associations	5	4	4	3	4
		Scientific Institutions	5	4	3	4	5
Results per Dimension—arithmetic mean (without weighting factors)		Management	5.500	5.500	1.500	2.250	2.000
		Human Capital	4.905	4.429	3.095	2.905	4.000
		Functionality (IT)	5.500	4.833	3.333	4.000	5.000
		Technology	4.941	4.882	3.765	4.353	3.412
		Information	5.125	4.250	4.125	3.500	5.125
DRIP Score (Index)			*5.195*	*4.871*	*3.088*	*3.512*	*3.730*

* PPI

Table 3 IT Capability Assessment

No	Sub-Indicator	Valencia	Klaipeda	Karlskrona	Wismar	Stralsund
6.1	IT infrastructure	4	5	4	5	5
6.2	Automation technology	4	4	3	2	5
6.3	Data analytics	5	5	3	2	6
6.4	Data security/communications security	5	4	4	5	5
6.5	Development of/application of assistance systems	6	4	3	3	4
6.6	Collaboration software	5	4	3	5	5
6.7	Non-technical skills such as systems thinking and process understanding	4	4	3	4	5
IT Capabilities (arithmetic mean)		*4.714*	*4.286*	*3.286*	*3.714*	*5.000*

Table 4 Strategic Graduation towards Smart Port Development

Port classification	Characteristics	Strategy description	DRIP Score (x)
Smart port	The port is completely connected via a communications network and fully integrated with its environment (i.e. all stakeholders of the industry) as well as other ports and logistics actors around the globe. Scheduling of the various transport modes is optimised and real time cargo tracking with all relevant players involved is enabled	Merge the physical and digital worlds. Ensure steady improvement by continuous development of sustainable and innovative business cases	$5.5 \leq x \leq 6.0$
Developer port	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 port targets on continuous improvement	Usage of digitalisation to create competitive advantage and maintain the competitive advantage by targeting on sustainable integration and ongoing enhancements. New businesses should be generated and ecosystem partnerships must expand	$4.5 \leq x < 5.5$
Adopter port	The port and immediately involved organisations (regularly: authority, operator, customs, etc.) started to integrate their (information) systems in order to achieve better communication. Hence, a small single digital environment will be created and several advantages such as better coordination and reduction of waiting times for all means of transportation can be achieved. The environment is perceived	Prioritisation of customer relationships depending on own processes and service structure. Strategic decisions should be driven by analytics. Act on environmental changes and consider them in decision making process. Overall new business opportunities should be identifiable	$3.5 \leq x < 4.5$
Monitor port	Individual automations in the port might emerge. Port authority, operator and related organisations in the near proximity of the port maintain their own processes and databases as well as started to digitalise them individually. Accordingly, information and relevant data is capture across specific nodes. The port environment is monitored. Regarding the customers, a statistics driven policy is driven	Focus and improve adaptive capacities. Especially skills and knowledge of employees on all hierarchical levels should be enhanced, whereby outsourcing strategy for digital expertise represents a suitable alternative. Try to change observer role (slightly) to a more pro-active role	$2.5 \leq x < 3.5$
Analog port	Automation do not exist. The port has no or less knowledge about digitalisation and thus, do not know how to change or is not willing. Furthermore, the port performs usually the landlord functions. Regarding customers, the first-come-first-serve policy is usually applied	Change attitude by getting awareness of benefit and added value that comes from a sustainable digital development (i.e. digital transformation). Start sensing and shaping	$1.0 \leq x < 2.5$

high level as the seaport of Valencia. However, a need for action is noticeable regarding all other dimensions ("Human Capital" = 4.429, "Functionality (IT)" = 4.833, "Information" = 4.25). According to the assessed digital readiness index of 4.871 and with regard to Table 4, Klaipeda port may be classified as a "Developer port", too.

On the third place ranks the German seaport Stralsund, since the digital readiness assessment in Table 2 shows a score of 3.73. Stralsund in the BSR do not belongs to the TEN-T and thus, can be categorised as a small port. This is also noticeable according to the overall in- and outgoing cargo of about 2,000,000 t in 2019, whereby the major focus lies on the handling of "Dry bulk goods" with ca. 80%. Next to this, in 2019, about 16,500 passengers passed through the BSR port. By analysing the results of Table 2, it becomes obvious that for the dimension "Information", the same result was achieved as the best practice example Valencia (both: 5.125). Also the result that refers to the dimension "Functionality (IT)" can be evaluated as sound (5.0). Moreover, it is a little bit surprising that the findings of Table 3 suggest that for the PPI "IT Capabilities", the seaport of Stralsund exhibits the greatest digital performance among all investigated ports in this study. Moreover, this highlighted peculiarity was also detectable in the frame of further indicators that are apparent in Table 2. Nevertheless, an urgent need for action is given concerning the dimension "Management" (2.0), "Technology" (3.412) and lastly "Human Capital" (4.0). However, the overall result of Stralsund with an index of 3.73 suggests that this port can be categorised as an "Adopter port" (cf. Table 2 and 4).

The other German seaport Wismar is on the fourth place in the current study with a digital readiness index of 3.512 (cf. Table 2). The seaport of Wismar is a comprehensive port according to the TEN-T and thus, may be regarded as a medium-sized port. In 2019, the overall cargo throughput was 6,091,976 t. Thereby, about 91% are attributable to "Dry bulk goods". In contrast to this, only 4,445 passengers transited the BSR seaport in 2019. Compared to the best practice example (Valencia seaport), considerable backlog is observable throughout all dimensions ("Management" = 2.250, "Human Capital" = 2.905, "Functionality (IT)" = 4.0, "Technology" = 4.353, "Information" = 3.5) in the case of seaport of Wismar (cf. Table 2). Nevertheless, the overall DRIP score of 3.512 (cf. Table 2) suggests that Wismar seaport can be classified according to Table 4 only just as an "Adopter port".

On the last rank, the Swedish port Karlskrona achieved an overall digital readiness score of 3.088 (cf. Table 2). According to the TEN-T, Karlskrona is classified as a comprehensive port, too. However the medium-sized port handled in 2019 only ca. 450,000 t of freight. Moreover, the shares are distributed with 44% to "Ro-Ro mobile self-propelled units", 13% to "Ro-Ro mobile non self-propelled unit", 11% to "Containers" and 5% to "Dry bulk goods". In addition, in 2019, about 700,000 passengers transited the seaport. Therefore, it can be noted that Karlskrona represents rather a ferry port, since the share of handled cargo is quite low. Need for action is visible among all dimensions that are indicated in Table 2 ("Management" = 1.5, "Human Capital" = 3.095, "Functionality (IT)" = 3.333, "Technology" = 3.765, "Information" = 4.125). In sum, the achieved digital readiness index of 3.088 by the BSR seaport Karlskrona results—in accordance to Table 3—into the categorisation as a classical "Monitor port".

Lastly, the typical characteristics as well as the related current strategical positioning of each port and the concrete strategic recommendations—towards a smart port development—that apply for each port classification (i.e. "Analog port", "Monitor port", "Adopter port", "Developer port" and "Smart port"), dependent from the achieved score based on the DRIP assessment from Table 2, are described in detail in Table 4.

5 Discussion

The digital readiness index for ports (DRIP) embraces 5 dimensions and 38 related indicators (cf. Tables 1 and 2). As mentioned by Philipp et al. (2020b), these five dimensions (i.e. "Management", "Human Capital", "Functionality (IT)", "Technology" and "Information") were incorporated into the digital auditing tool, since the digital transformation of ports is not safeguarded by only using innovative technologies. It is more the interplay of management measures and employees' knowledge and skills, as well as functional IT processes and systems with these digital technologies that ensures a sustainable development towards a smart port. Moreover, it is essential to guarantee a comprehensive information procurement regarding current digitalisation trends. Through this, port representatives can inform themselves and receive awareness of achievable added value that comes from a sustainable digital development. Furthermore, this ensures the proper identification of adequate actions and investments during the strategic decision-making process.

The indicated weighting factors in the DRIP model represent the importance of each dimension, which had been determined during expert interviews with project experts. The distribution of the importance or weight, respectively, between the dimensions in the presented digital readiness assessment model may represent a subject for future discussions. The experts of the Connect2SmallPorts project emphasised that this weighting factors might be subjective, but undoubtable a weighting of the dimensions needs to be incorporated in the indexing procedure, as the five dimensions cannot be regarded as equal important. Against this, in the current DRIP model all indicators are equally weighted in each dimension, which may represent another subject of discussions. However, all PPIs and further chosen indicators 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. Nevertheless, the weighting of the different dimensions and indicators might be adjusted in other situations by respecting the regional peculiarities, economic perspectives and stakeholders' interests.

Another potential subject for discussion could be seen the assessment of the PPI "IT Capability" via the seven sub-indicators in Table 3. In this context it might be argued that especially "IT Capabilities" represent an essential—if not the most important—source for a sustainable development towards a smart port. Hence, possibly these sub-indicators should receive more weight through the incorporation as full indicators in the overall DRIP model, which is equal to a direct integration into the tool next to the 38 already fully acknowledged indicators. However, in this present study they had been separated, since they all refer to the same holistic indicator "IT Capabilities", which was weighted with the same importance as the PPIs "IT Knowledge & Skills" and "IT Training & Education Opportunities" in the dimension "Human Capital".

By taking into account the presented strategic graduation towards a smart port development, which is showcased in Table 4, it can be further noted that the previously applied digital readiness index for ports is extended by a component of a maturity model. Accordingly, building upon the benchmarking and indexing of the ports via the DRIP, the current strategic positioning of the ports based on the respective digital performance that is characteristic for each of the different digital port types becomes obvious. As emphasized in Table 4, through this, the respective strategic recommendations for a sustainable development towards a smart port can be derived in accordance to each port classification. Accordingly, for both, Valencia and Klaipeda port that can be classified as "Developer ports", it might be strategically suggested to use the achieved high digitalisation degree for the creation of a competitive advantage and to maintain the competitive advantage by targeting on further and broader sustainable integration of the hinterland and thus, to extended the network of stakeholders by exceeding the hinterland. Moreover, new businesses should be generated, whereby ecosystem partnerships should expand. Regarding the two German ports (i.e. Stralsund and Wismar), that both can be categorised as "Adopter ports", it might be suggested to prioritise the customer relationships depending on own processes and service structure. Furthermore, strategic and other decisions should be driven by analytics, whereby environmental changes must be stronger and more thoroughly taken into account during decision-making process. Another strategic goal should be seen in the identification of new business opportunities. Concerning the Swedish port Karlskrona that is evaluated as a "Monitor port", it can be suggested to focus and improve the adaptive capacities. Especially the capabilities and knowledge of the employees on all hierarchical levels should be increased, whereby the outsourcing strategy for the acquisition of digital expertise represents a suitable alternative in the frame of the overall digitalisation strategy. Finally, Karlskrona port should try to move from an observer role to a more pro-active one.

6 Conclusions

Port performance measurement has a long-standing history. Nevertheless, existing PPI-concepts in theory and practice mainly focus on operational performance measurement in container ports. Hence, next to the obvious target-group limitation, there exist a lack of concepts and models for measuring the digital performance of ports. As the research revealed, the developed DRIP concept by Philipp et al. (2020b), which was so far only on a theoretical basis proposed, but now, in this study practically applied for the first time, represents a suitable and appropriate tool for auditing the digital performance of ports.

By taking into account the presented strategic graduation model towards a smart port development, it can be concluded that in the present study the previously applied DRIP concept became a maturity model. Furthermore, it can be concluded that through the indexing results of the investigated ports (i.e. DRIP score), which were generated by the application of the digital readiness index for ports, the current strategic digital positioning of the seaports became identifiable. Moreover, this ensured that the respective strategic direction (incl. strategic recommendations) for a sustainable development towards a smart port could be derived—in respect to the individual digital port classification.

Accordingly, through the presented and conceptualised port maturity model in this study that incorporates the DRIP concept from Philipp et al. (2020b) and the fitting strategic graduation matrix towards a smart port development, practitioners—i.e. especially port representatives like port authorities or operators, respectively—as well as researchers are able to assess the digital performance and readiness of ports, to identify the current strategic positing of ports in the digital context, to categorise the ports according their digital maturity status and to derive concrete digital strategic actions. Overall, through this, the roadmap for the digital transformation of ports towards smart port development was clearly stated by the definition of respective strategies in respect to the different digital port classifications. With other words, the developed maturity model can assist port authorities and operators as well as policy makers and other port-related stakeholders during decision-making, and is able to support the identification and definition of an efficient and effective strategic direction for setting up the roadmap for the digital transformation of the port. However, due to the lack of comparable research studies a general methodological limitation is apparent.

Additionally, through the incorporation of a growing number of ports in the frame of the future research activities and through the incorporation of PPIs that target to measure the operational performance of ports, it will be possible to investigate the potential relationship between the digital and operational performance of ports. Moreover, as an extra concluding remark for future research activities, it was also noticeable in this study that all investigated ports show low digital readiness in case of some digital technologies—e.g. "Blockchain (incl. Smart Contracts)" and "Artificial Intelligence (AI)". Despite the fact that there already exist research studies that targeted these topics (e.g. Henesey and Philipp 2019; Philipp et al. 2019b, 2019c; etc.), future research activities should stronger focus on proposing respective use cases, since the results of the present study showcased that so far these technologies have not or hardly been implemented and used in ports.

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BLOCKCHAIN AND SMART CONTRACTS FOR ENTREPRENEURIAL COLLABORATION IN MARITIME SUPPLY CHAINS

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Smart contracts are scripts on the top of the blockchain technology. They represent a form of automation by what the layers of intermediaries can be reduced or even completely replaced. Accordingly, blockchain smart contracting systems decrease transaction and enforcement costs as well as process time.

Moreover, we argue, blockchain and smart contracts can facilitate cross-organisational collaboration and their underlying business processes. Hence, they are able to support the integration of entrepreneurs and SMEs into trans-national supply chains by reducing high entry barriers and weakening the dominating position of big players.

This paper discusses the research questions how blockchain smart contracting can facilitate the implementation of collaborative logistics structures and how the integration of SMEs into sustainable maritime supply chains can be safeguarded. The research bases on expert interviews and case studies. The results showcase the potentials of using blockchain smart contracting in the environment of trans-national and multimodal supply chains.

Keywords: Blockchain, Smart Contracts, Maitime Supply Chains, SMEs, Ports, Entrepreneurial Collaboration

1. Introduction

Supply chain management targets to integrate different organisational entities of a supply chain as well as to manage efficiently materials, information and financial flows for greatly fulfilling customer demands with the objective of enhancing competiveness of the entire supply chain (Stadtler, 2005). Thereby, supply chains among other things refer to the interactions with suppliers, warehouses, distribution centres, retail outlets, raw materials, goods-in-process stocks and finished products (Simchi-Levi *et al*., 2003). Accordingly, due to many different interest groups, sophisticated business processes as well as distributed structure of supply chains, the management of the supply chain flows remains a challenging task (Prause, 2019). Moreover, further “evergreen” challenges in this context are related to the dominating position of big players, establishment of trust and relationships between the different actors, fragmented structures, supply chain finance and lead-time as well as throughput (Beth et al., 2013; Nyhuis and Wiendahl, 2008; Prause and Hunke, 2014; Zhao and Huchzermeier, 2018). In order to smartly tackle these issues, the current research efforts in logistics result into the evolvement of potential reorganisations for an efficient crossover from scattered supply chains to open logistics networks, where resources are accessible, compatible and intertwined (Rusich, 2018). Thus, in the context of Industry 4.0, a shift towards smart manufacturing with a focus on fractals, networked cyber-physical systems (CPS), self-organisation, self-optimisation and machine-to-machine systems (M2M) is noticeable (Prause and Atari, 2017). Therefore, challenges in the course of supply chain management become smarter, more networked, fragmented, decentralised and distributed (Prause, 2015; Olaniyi and Reidolf, 2015). This transition culminates in the new paradigm Logistics 4.0, also well-known as smart logistics, which can be understood as a management approach for developing, designing, managing and realising change-oriented networks of object flows (e.g. materials, information, values) based on pattern recognition, generalisation and self-organisation, enabled through the usage of new technologies and innovative services (Wehberg, 2016). In this context, among all novel technologies, one of the most promising approaches with far reaching potentials is the blockchain technology including smart contracts.

Smart contracts are computer codes that run on the top of the blockchain technology. They are a very simple form of automation with "if-then-else" functions. Accordingly, smart contracts represent transactional protocols or scripts that can execute and enforce legal contracts. Thereby, they self-executable permanently audit the achievement of pre-defined and previously agreed terms and conditions that are coded and stored on the blockchain ledger, including new uploaded and up-dated data and documents. Through this automated reconciliation, smart contracts can trigger in real-time respective actions or transactions, respectively, as soon as the pre-defined contractual clauses and rules are fulfilled.

In the course of supply chain management high interest is given, since especially information intermediaries can be reduced or fully replaced by the implementation of blockchain smart contracting systems. Furthermore, smart contracts and in particular, the underlying blockchain technology, bear the potential to decrease transaction and enforcement costs along supply chains. Building upon this, we further argue that smart contracts applications on a blockchain platform in the areas of logistics networks and supply chains support the integration of entrepreneurs and SMEs into trans-national value and supply chains, which are currently still closed due to high entry barriers or to domination of big players (Prause and Hunke, 2014; Prause and Hoffmann, 2017).

The authors took place in several EU-projects with focus on green logistics and sustainable supply chain management, and where resulting research studies confirmed that especially in the context of Industry 4.0, SMEs can benefit (e.g. Prause and Atari, 2017; Gerlitz, 2017, 2015). Hence, the current research paper discusses the research question how smart contracting and blockchain technology can facilitate the implementation of collaborative logistics structures and how the integration of SME sector into sustainable trans-national maritime supply chains can be safeguarded. To address this issue, we use two case studies. The first case study refers to a simplified charter-party contracting process within a single voyager in the freight market, whereas the arising advantages of an adequate technology implementation are highlighted. In contrast to this macro-logistics level perspective (i.e. port environment), the second case study concentrates on a micro-logistics level, whereby the immediate port sector – cargo import case – is addresses. Hence, the case study of the medium-sized seaport of Wismar is used to showcase the potentials of blockchain technology and smart contracts to simplify the port logistics processes with increased efficiency.

Generally, the research study refers to expert interviews and case studies from several EU-projects with a focus on the two ongoing projects "Connect2SmallPorts" and "CSHIPP", which are implemented in INTERREG VA South Baltic and INTERREG VB Baltic Sea Region programmes. The research findings will highlight that smart contracts and blockchain technology create great advantages for SMEs, since their competiveness and efficiency can be enhanced and participation ensured through the adoption of this new technology due to lower transaction costs and disintermediation.

The paper is structured as follow: The second chapter provides insights to the blockchain and smart contract technology by a literature review. Building upon this, the research method is set out. In the fourth section, the research findings and discussion based on the two case studies of a (1) charter-party contracting process within a single voyager in the freight market, and (2) the medium-sized seaport of Wismar are showcased. The paper rounds up with a conclusion.

2. Literature Review

Intellectual roots of the blockchain technology can be traced back to Satoshi Nakamoto in 2008 (Nakamoto, 2008). Blockchains are comparable with open and distributed ledger systems that facilitate via alphanumerical code (i.e. address account) and private key the secured execution of transactions in a virtual network with untrusted parties. Thereby, for the cryptocurrency exchange intermediaries are superfluous, which represents one of the special features of the blockchain technology that among other things ensures the development of a decentralised network of trust (Chuen, 2015; Gallay *et al*., 2017; Liao and Wang, 2018; Manski, 2016; Swan, 2015). This is, because each independent participant receive a copy of the ledger for own control purposes. Accordingly, next to intermediaries, this distributed virtual ledger system can supplant physical documents as well as signatures. As highlighted by Wu (2018), especially this decentralised and distributed feature of the blockchain technology can foster the competiveness and efficiency of entrepreneurs and SMEs through enhanced information accessibility, reduced risks and levels of intermediaries, which result in a decrease of transaction and intermediary costs. Accordingly, by taking one-step further, it can be argued that the blockchain technology bears the potential to facilitate entrepreneurial collaborations in trans-national supply chains.

Smart Contracts – also known as digital contracts or e-contracts – expand the initial blockchain application and suggest wider use cases (Gallay *et al.,* 2017; L'Hermitte *et al*., 2018; Swan, 2015; Wu, 2018).

They represent transactional scripts or protocols that include terms and conditions of contracts. Building upon on a blockchain platform, where they are implemented through digital codes with software, smart contracts automatically process the negotiated conditions of contracts to which all involved parties previously agreed (Liao and Wang, 2018). Accordingly, they are stand-alone programmes that audit the pre-defined conditions of an agreement, which was concluded between at least two parties. Furthermore, they are able to conduct reconciliation with new transactions – or even recent uploaded and updated data and documents that had been added to the blockchain ledger by IoT applications. This procedure is permanently self-executable performed by smart contracts. As soon as all pre-defined terms and conditions are fulfilled, smart contracts automatically trigger a certain number of actions or transactions – dependent from the purpose they were originally programmed (i.e. according to their script) (Kouhizadeh and Sarkis, 2018).

With other words, smart contracts are able to read from and write on the blockchain. In addition, they ensure that whenever a certain transaction or action occurs, further transactions or actions are conducted automatically (García-Bañuelos *et al.,* 2017). Therefore, it can be stated that smart contracts ease and validate the completion of contractual agreements. Thereby, they represent a very simple form of decentral automation with "if-then-else" functions. As a result, the intermediaries and the existence of trust in the area of contractual agreements become superfluous (Liao and Wang, 2018; Kouhizadeh and Sarkis, 2018). All this fosters the development of DOAs (decentralised autonomous organisations) (Manski, 2016).

To summarise, the contractual conditions as well as related legal principles are coded as algorithms in smart contracts, which are transparent, since they are stored on the decentralised and distributed blockchain network, and thus, shared with their digital record and signature under the contract parties (Kouhizadeh and Sarkis, 2018). Through this, the characteristics of the blockchain technology effect smart contracts and make them more protected against distortions, revisions and manipulations as well as deletion (Liao and Wang, 2018). Since also the utilisation of smart contracts further incorporates the potential to remove the value of interposed or so far necessary intermediaries (e.g. third parties, middlemen, brokers or agents like governments, banks, lawyers, etc.) in various business activities, they can additionally decrease transaction costs as well as facilitate the efficiency and redesign of complex business structures that are characteristic for supply chains.

3. Method

The research on smart contracts and blockchain technology in the nexus of maritime logistics sector, and in particular in the context of small and medium-sized seaports, have not sufficiently investigated so far (Liao and Wang, 2018). Hence, to the best of our knowledge, currently there exist no published work that discussed how smart contracting and blockchain technology can facilitate the implementation of collaborative business structures for sustainable trans-national entrepreneurial activities in maritime supply chains. According to Creswell and Creswell (2017), if a concept or phenomenon needs to be understood, because less research has been done on a specific topic, especially the qualitative research approach is suitable. Therefore, in the frame of the current research study, the decision was made to favour a qualitative research approach. Nevertheless, the research was performed based on simultaneous procedures, where quantitative as well as qualitative data was synthetized in order to efficiently tackle the identified research problem (ibid.). Hence, the authors gathered primarily qualitative as well as quantitative data, and combined the received information in the frame of the interpretation process that is reflected by the presented holistic research results. The qualitative research in the present research study represents a narrative research. In the course of narrative research, the gathered information from experienced individuals is condensed and retold by the researchers (ibid.). The authors of the present research study performed 21 semi-qualitative expert interviews with relevant project experts, scientists as well as project interest groups that took place during November 2018 and March 2019. These expert interviews mainly embraced open-ended questions, whereby a quarter of the questions represented closed-ended questions that grounded on a five-point metric scale. Building upon this, two case studies were performed in the current research study. The research was complemented by field research and observations, an extensive literature review, analysis and examination of respective theories and approaches, topic-related policy regulations and guidelines, representing a systematic research procedure for the elaboration of a process, action and/or interaction about a substantial subject (ibid.). By doing so, the researchers identified common functionalities of a sustainable usage of blockchain smart contracting systems (1) in the context of a charter-party contracting process within a single voyager in the freight market, as well as (2) in the immediate environment of a medium sized seaport; and thus, were able to present the advantages of the technology adoption as well as related grassroots guidelines for an efficient implementation.

In frame of case studies, programmes, events, activities, processes or individuals are investigated in depth (Creswell and Creswell, 2017; Yin, 2009), where profound information is gathered by using a wide range of data collection activities in a certain time frame (Stake, 1995). In the course of the presented case studies in this research paper, the researchers got involved with the primary target group that is defined by: policy makers that are responsible for infrastructure and port development; port and terminal operators; forwarders; international organisations and institutions that refer to port-related supply and value chains; shipping companies and/or lines; research institutions; local and regional industries that are interested in digitalisation issues and governmental investments as well as higher data security.

The focus of the empiric research activities laid on the following ongoing INTERREG projects: (1) “Connect2SmallPorts” and (2) “CSHIPP”. The Connect2SmallPorts project focusses on improving cross-border connectivity for a functional blue and green transport area, with the objective to improve the quality and environmental sustainability of transport services in South Baltic Sea Region. In contrast, the CSHIPP project focalizes on sustainable transport, with the objective to enhance clean shipping based on increased capacity of maritime actors of the whole Baltic Sea Region (i.e. environmentally friendly shipping). Through active collaboration and in some cases leadership (Connect2SmallPorts) by the researchers in the different cross-border research projects, access to a wide range of data and insights on the research topic is ensured, which was crucial and the stepping-stone for the current research. Next to the public stakeholders, especially, the private organisations that participate as project partners in the EU-funded projects delivered essential insight into their business practises and the status-quo of blockchain and smart contracts in the environment of maritime logistics sector and specifically in the context of small and medium-sized ports.

Relevant information and observations were gained from a broad field of project actions like project partner meetings, workshops, trainings, matchmaking events as well as logistics and open seaport-related conferences with project interest groups. In addition, focus group meetings had been performed for a stronger target-oriented investigation of particular topics of interest. These focus group meetings were mainly conducted in the course of the EU-project Connect2SmallPorts, which also targets to explore use cases and new business models that arise from the potential application of the blockchain technology in the context of small and medium-sized seaports in South Baltic Sea Region. Moreover, additional primary information were gathered from individual meetings with experts from the logistics and IT sector, which supported the collection of information about the presented cases, related challenges and potential implementation procedures. These meetings were conducted with decision makers of the ports from Wismar (DE), Rostock, Stralsund, Vierow, Karlskrona (SE) and Klaipeda (LT). At the same time, phone conferences and Skype meetings assisted this data and information collection process. The logistics and seaport-related conferences, where the authors participated, spurred the information exchange with further stakeholders. Hence, the exchange and collaboration with numerous different stakeholder groups allowed the achievement of a more comprehensive perspective on the topic.

To sum up, the qualitative research approach safeguarded the examination of the identified research problem in a comprising manner. The novel topic – blockchain smart contracting system – was described fundamentally by the literature review. Building upon this, the potential adoptions of this new technology in the context of (1) charter-party contracting processes, as well as (2) small and medium-sized seaports is described in the following in form of use cases. Thereby, observations, expert interviews, focus group meetings and case studies were used as the main methods of the present research study. Based on the presented research findings, the authors were capable to achieve the indicated research objective and to answer the related research question in a qualitative manner. Lastly, the presented research results were validated and verified by the abovementioned primary target groups in the course of project-induced workshops, trainings and seminars.

4. Findings and discussion

The subsequent first case study exemplifies a simplified charter-party contracting process within a single voyager in the freight market, whereby the arising advantages of an appropriate technology implementation are emphasized. Contrary to this macro-logistics level perspective (i.e. port environment), the second case study focus on the micro-logistics level, since the immediate port sector – cargo import case – is described. This illustrated cargo import case is characteristic for the medium-sized seaport of Wismar in Germany, but to a certain degree also applicable or generalizable, respectively, to other seaports that focus on break-bulk cargo. Through this, a clear presentation of emerging potentials that are achievable through the adequate implementation of the blockchain technology and smart contracts is ensured and result in simplified port logistics processes with increased efficiency.

4.1. Charter-party contracts

In order to exemplify the various benefits that arise from a potential implementation of the blockchain technology and smart contracts on a macro-logistics level, we use and describe a simplified charter-party contracting process within a single voyager in the break-bulk market. In a first step, the present situation in the freight market is presented, which is followed by an in-depth analysis and exposition of achievable improvements in order to arrive at an optimised process flow, which can be ensured by the integration of a potential blockchain smart contracting system. The general charter-party contracting process comprises four phases: (1) pre-fixture, (2) fixture, (3) post-fixture loading and (4) post-fixture discharging.

In the pre-fixture phase, the process generally starts with a charterer, who has a fixed sales contract with a supplier or processors – for e.g. wood logs (i.e. break-bulk cargo). Since in the charter-party contracting process many different actors are involved, in our simplified case the charterer is also the trader and/or shipper, or at least closely related to them. In order to deliver the cargo, the charterer seeks for a vessel that is suitable to transport the respective freight. Accordingly, the charterer wants to conclude a contract with a ship-owner. The task to find a suitable ship for a specific type of cargo is usually delegated to a shipbroker, whereby generally both parties (i.e. charterer and ship-owner) have their shipbrokers, and even the interposition of a third shipbroker between the charterers' and ship-owners' shipbrokers is also possible. However, usually the charterer appoints the shipbroker, who checks the current market situation. In order to perform this task, the charterer has to provide the shipbroker with initial information regarding name and address as well as contact details of charterer, cargo type and quantity as well as physical dimensions, loading and discharging ports and rates, expected laycan, etc.

Subsequently, in the fixture phase, the shipbroker seeks for a suitable ship according to the indicated freight features, desired period of time as well as expected rate(s). Accordingly, the shipbroker contacts several ship-owners and starts the negotiation process on behalf of the charterer. Depending on the specific conditions of the envisaged contract, the individual market situation and the network of the shipbroker, this search process may take some hours, but often a few days or even weeks. Finally, when the shipbroker found a suitable vessel according to the desired conditions, the offer with initial terms and conditions from the charterer is send to the ship-owner by the shipbroker. Then, the ship-owner checks the received offer and conducts respective pre-calculations, which result in the sending of the initial time charter or freight rate (here simplified as the general charter rate) to the shipbroker, who then forwards it to the charterer, whereby in some cases the appointed shipbroker also has an initial charter rate idea. The process of negotiation starts and can result in a consensual agreement, a counteroffer, or a disagreement. Accordingly, this procedure may takes some time due to potential emergence of circulating counteroffers, whereby the additional problem occurs that the related documents and/or offers are send back and forth – often still via a courier. Generally, the shipbroker function as the information intermediary between the charterer and the ship-owner. Hence, each decision or information of the charterer or ship-owner is firstly shared and communicated with the interposed shipbroker, before it is forwarded to the charterer or ship-owner. When the charterer and ship-owner finally agreed to the negotiated charter rate, terms and conditions, the shipbroker drafts the respective contract that includes the aforementioned information, which is then forwarded to the charterer and ship-owner for final fixture. Accordingly, the charterer and ship-owner audit the received charter-party contract form and if all necessary information are correct and included, they sign the contract. Usually sound charter-party contracts are quite comprehensive, since they cover many important and crucial information, e.g. details regarding the ship-owner and charterer as well as shipbroker, ship details, brokerage fee (commission), charter rate, cargo and carriage specifications, loading and discharging ports and rates as well as dates, laytime, demurrage and despatch rates, freight payment, payment terms and details including currency, and other obligations and rules as well as clauses. Hence, charter-party contracts also contain legal aspects and clarify responsibilities, also for cases of unexpected events and rules that apply in case of non-performance. Due to the complexity and wide range of potential uncertainties that must be hedged in charter-party contracts, in practice, there exist typical standard templates. For instance, in case of voyage charters common standard charter-party contract forms that are used are among other things NUBALTWOOD, GENCON, etc. Vice versa, in case of time charters well-known standard forms are ASBATIME, BALTIME, GENTIME, LINERTIME, NYPE, etc. These templates cover the most relevant clauses that must be taken into account when concluding a charter-party contract.

In the post-fixture loading phase primarily monitoring tasks are performed. Usually, both the charterer and the ship-owner are not personally present at the loading as well as discharging ports. Hence, port agents are appointed at the exporting and importing ports, who are equipped with the necessary information, instructions and rights. Related decisions are also negotiated and then incorporated in charter-party contracts during the fixture phase. Accordingly, the port agent at the origin port monitors the lading sub-process, stevedores, bills of lading, notice of readiness statement (NOR) and vessel's statement of facts (SOF), etc. In addition, he sends progress reports about the status to the charterer and ship-owner, as well as checks and transmits the freight receipt.

The post-fixture discharging phase on a first glance similarly embraces mainly monitoring tasks. Accordingly, in the frame of the discharging sub-process at the destination port, the port agent controls the discharging progress, notice of readiness statement (NOR) and vessel's statement of facts (SOF), payment status, etc. This includes as well the transmit of progress information to the charterer and ship-owner. When the vessel is discharged, the charterer and ship-owner start to conduct concluding calculations according to the previously agreed terms and conditions in the charter-party contract and actual performance. If the charterer and the ship-owner come to a joint and concluding outcome, the charterer pays the ship-owner and the ship-owner arranges the payment of the shipbroker, regardless whether the charterer appointed the shipbroker and independently whether more than one shipbroker was involved in the process. Vice versa, if the ship-owner and the charterer do not reach a joint consensus in the frame of the performed concluding calculations and thus, the respective receipt, a dispute may arise, which can result in additional delays regarding the payment sub-process. This can lead to the involvement of the shipbroker as a mediator or lawyers and courts. Therefore, in order to avoid such problems, it is essential that the previously concluded charter-party contract is detailed and robust.

The described general charter-party contracting process incorporates many options for enhancements that can be partly empowered through the implementation of the blockchain or smart contract technology, respectively. Hence, for enhancing the charter-party contracting process, a blockchain driven smart contracting system is proposed, which targets among other things to directly connect the charterers and the ship-owners. Next to this, especially the information and cargo flow of the overall supply chain, as well as entrepreneurial collaborations can be improved.

In the course of the pre-fixture phase, the charterer is looking for a suitable vessel and the ship-owner searches for freight that needs to be transported from an origin to a destination port. Thereby, relevant information from charterers' side are cargo type and quantity as well as physical dimensions, loading and discharging ports, expected laycan, etc. Against this, the well-needed information from ship-owners' side are ship type and size, current position, period of availability, etc. In the abovementioned current situation, usually the charterer appoints a shipbroker for the generation of offers according to the respective situation on the market – in our case the respective situation on the break-bulk market. Therefore, the shipbroker administers the received information of both parties, and based on this, seeks for suitable matches. This initiation phase can be eased by an information-sharing platform that is implemented via the internet. Such comparable platforms already exist, whereby one of the most prominent representatives is OpenSea.Pro, which is a web-based chartering marketplace system that simplifies the tasks of shipbrokers. This is, because the platform eases the monitoring of the respective situation on the global freight market in real time, streamlines the search process for matches through the entered and stored data of ship-owners and charterers, as well as facilitates the communication process with both parties and the shipbroker. Accordingly, in practice, there exist already virtual marketplaces, where ship-owners and charterers could easily find each other and make contact, if their uploaded profile, entered data, conditions and requirements are of interest for at least one party. Thus, these platforms are able to connect the ship-owners and charterers directly without the necessity to interpose a shipbroker. Especially this can streamline the matchmaking sub-process, which shortened time, eases the communication as well as ensures the exchange of data and information – even in later stages of the cargo voyage. Moreover, this pre-fixture phase that can be facilitated through the implementation of a virtual marketplace also represents the potential initial starting point for the realisation of a blockchain and smart contract application. For instance, the virtual marketplace can be implemented and work based on the blockchain technology with additional smart contract applications. A smart contract application could compare the shared initial data from charterers and ship-owners that is provided on the web-based marketplace platform, and thus, can automatically check whether the pre-conditions for a match are fulfilled. Building upon this, a kind of pre-contracts can be automatically generated as well by the smart contract application, since the shared data of the participants represents at the same time the initial information and pre-conditions that must be fulfilled for the aspired development of a charter-party contract.

The fixture phase is primarily characterised by negotiation activities between the ship-owner and the charterer, whereby the overall information flow is organised via the interposed shipbroker. Once a suitable ship was found according to the pre-defined conditions, the shipbroker sends the initial offer to the ship-owner. Then, the ship-owner audits the received offer and conducts respective pre-calculations, which can result into the sending of the calculated charter rate to the shipbroker, who forwards it to the charterer. Generally, this negotiation process can result in a consensual agreement, a counteroffer, or a disagreement, and thus, can be extremely time-consuming, as this process is not automated. However, when the ship-owner and charterer agreed to the charter rate and other terms and conditions, the contract will be prepared by the shipbroker according to the previous negotiated and agreed rates and clauses for final fixture. Also in this process phase, the implementation of a blockchain smart contracting system would achieve great advantages. For example, Norta (2015) developed a smart-contracting setup lifecycle for the negotiation procedure, which can be seen as a viable foundation for the transition to a smart charter-party contracting system. On the other hand, the wide acceptance in practice and thus, usage of standard charter-party contract forms additionally encourages the potential of automation via smart contracts, since both actors (i.e. ship-owner and charterer) appreciate that such templates for charter-party contracts cover the most important clauses that need to be taken into account. Furthermore, indices like the Baltic Dry Index that are used in practice function as orientation (e.g. hurdle rate) in the course of price negotiations. This respective market data as input data can be automatically integrated in the smart contracting negotiation process. Once the charterer and the ship-owner have jointly agreed on the rates and terms, the charter-party agreement is fixed, and is automatically generated through the underlying smart contract application. Moreover, the elaborated and fixed charter-party contract is stored and secured on the blockchain. Accordingly, the fixed charter-party contract becomes decentralised secured, fraud-resistant, immutable, transparent and permanently auditable and accessible for all involved stakeholders during the cargo voyage – if permission is granted.

In the post-fixture loading phase, primarily monitoring activities are performed that are mainly in the area of responsibility of the appointed port agent at the loading port. These monitoring tasks are related to the loading progress, stevedores, bills of lading, notice of readiness statement (NOR) and vessel's statement of facts (SOF), etc. The status information about the port operations are forwarded to the ship-owner and charterer by the port agent, and function as important input data for the concluding calculations in the post-fixture discharging phase. In the actual situation, this embraces the back and forth sending of physical documents, copies and time sheets between all involved parties. Accordingly, also in this phase, the potential integration of the blockchain technology can optimise the process flow. For instance, by the additional incorporation of IoT applications – especially smart devices – the respective information about the loading activities in the origin port can be uploaded and stored on the blockchain in real-time. Through this, all necessary information or documents, respectively, become decentralised secured, fraud-resistant, immutable, transparent and permanently auditable and accessible for all involved parties. Since smart contracts can read from and write on the blockchain, important documents like vessel's statement of facts (SOF) or bills of lading can be automatically elaborated by an implemented smart contract application – if all pre-defined conditions are fulfilled and thus, all relevant data and information is available on the blockchain ledger through further uploaded, secured and shared files.

During the post-fixture discharging phase, comparable monitoring tasks occur as in the post-fixture loading phase, which result again in the flow of information between all involved participants. Therefore, also in this sub-process, blockchain smart contract applications are reasonable: IoT and smart contract applications feed the blockchain ledger with needed input data and smart contracts process these information and data in order to trigger further transactions or actions, respectively. Furthermore, next to the monitoring activities, this phase includes the concluding calculations, which need to be performed by the ship-owner and charterer. This is conducted based on the formerly fixed charter-party contract as well as all collected information and data that was generated during the entire voyage of the freight. Generally, this should result in the payment of the ship-owner for his service. These activities can be optimised, since they can be automated via an implemented blockchain smart contracting system. In addition, the calculation process of all related expenses like demurrage and despatch can be automated via smart contracts, too, since the needed rates are recorded in the charter-party contract, which is secured on the blockchain ledger in our optimised process. Moreover, all other important input data that is needed for the concluding calculations via implemented smart contract application, is provided in our optimised process flow through the incorporated IoT applications. Accordingly, building upon all secured and thus, available information and data on the blockchain ledger, which was generated by all involved process parties during the entire cargo voyage as well as IoT applications, a smart contract application is able to elaborate automatically also the respective invoices – next to the automated calculation of related expenses. Additionally, if all conditions and requirements are fulfilled, the smart contract application is also able to trigger automatically the related transactions (i.e. payments) in accordance to the automatically generated invoices. Ensured through the implementation of a smart contracting system in the concluding calculation and payment process, the emergence of objections by the ship-owner and charterer can be limited, due to the decentralised nature of the blockchain and smart contract technology. Additionally, this is also deeply rooted in the fact that the automated expense calculations lie on the documents and data that had been worked out by the port agents, as well as on the formerly agreed and sign charter-party contract, which includes all agreed rates and terms. Accordingly, this procedure guarantees a trustful and fair approach for automated concluding calculations. Hence, a dispute between the ship-owner and charterer is less likely. Vice versa, this makes the involvement of courts and lawyers, or the shipbroker as a mediator superfluous, which at the same time prevents against additional delays of the payment sub-process and thus, the overall process.

The benefits of an implemented blockchain smart contracting system in the ecosystem of a virtual marketplace are manifold. Through the incorporation of IoT applications, the cargo flow becomes trackable and the needed data generation for the smart contract applications is ensured, whereby among other things the integration of GPS shipping data could even foster this development. Moreover, the data exchange between incompatible systems is avoided and the data transfer becomes digital and automated, which result in a higher flexibility, streamline of the process and saves time, since no back and forth sending of physical documents via courier is necessary. Hence, all relevant documents and data are stored on the blockchain ledger, which guarantees availability at all times and for all involved stakeholders during the entire cargo voyage. Accordingly, this replaces the physical paperwork (i.e. multiple versions of files, signatures, etc.), whereby each party can digitally sign via a private key, validate files and generate copies, if necessary. Since during each cargo voyage, many but every time different actors are involved, a permissioned blockchain would be an appropriate solution. This is reasoned by the fact that within a permissioned blockchain, it is possible to clarify access and modification rights of the participants as well as proof of personal identification. Accordingly, specific transactions or actions can be set as private to certain participants. For instance, this might be useful in case of price negotiations and the result thereof. Generally, this can be regarded as a data filter, which ensures that only certain authorised parties are allowed to add, receive or inspect respective data and information that is needed for further tasks in their area of responsibility. Moreover, a simultaneous document processing and process tracking can be achieved, which supports the overall process transparency. Besides this, through the blockchain storage, all relevant documents become decentralised secured, fraud-resistant, immutable, transparent and permanently auditable and historically retraceable as well as accessible for all involved and authorised parties during the cargo voyage. This fosters trust among all involved actors and enhances efficiency of the entire process due to a higher flexibility. In addition, this blockchain recording procedure, delivers great fields of application for smart contract programmes. For instance, important documents such as the charter-party contracts can be generated automatically, if all pre-defined conditions are fulfilled that are available through the shared and stored data on the blockchain ledger. This includes as well the automation of the auditing procedures in case of documents and negotiations, as well as the inclusion of external available market data – e.g. the Baltic Dry Index on the freight market for price negotiations. Lastly, concluding calculations can be also automated by a smart contract implementation, as the necessary data basis is available through the underlying blockchain ledger. Through this, a smart contract application is able to automatically elaborate the final invoices, and if all conditions are fulfilled can trigger automatically the related payments. Hence, a blockchain and smart contract installation ensures a trustful and fair approach for the calculation of expenses as well as for monetary transactions. To sum up, all these highlighted aspects decrease costs due to shortened process time and lower manual works.

However, next to all showcased benefits, in particular the potential exclusion of the shipbroker as the central information intermediary between the ship-owner and charterer can have far-reaching positive impacts on maritime supply chains. It is obvious that through the introduction of a blockchain smart contracting system for the generation and conduction of charter-party contracts in the ecosystem of a virtual marketplace, the shipbroker becomes superfluous. With other words, the implementation of a smart charter-party contract system replaces the shipbroker and thus, reduces the layers of intermediaries in maritime supply chains, since the direct connection of the charterer and ship-owner is ensured. Enabled by the smart contract automation on a web-based marketplace, the ship-owners can transparently show their service supply and period of availability to the charterers, who can similarly indicate their time-bound service demand to the ship-owners. All this can be achieved without the necessity of an interposed shipbroker. Through this, the information flow is shortened, which in addition saves time. The formally given trust through the presence of the shipbroker is compensated by the decentralised nature and further benefits of the introduced blockchain and smart contract technology, which automatically leads to the emergence of trust among all involved users. Moreover, through the exclusion of the shipbroker, there are cost savings that have potential spill-over effects. For instance, as a direct impact, the brokerage fee or commission is saved by the ship-owner. Depending whether a voyage charter or a time charter is achieved, the involved shipbroker receives a commission on the gross freight or hire price for the vessel. Next to this, the brokerage fee is also dependent form further factors, such as type of cargo, kind of fixed ship, negotiations and agreements with the ship-owner, etc. Nevertheless, within voyage charters the commission usually varies between 1 and 5%. Contrary to this, within time charters, the brokerage fee amounts typically 2.5% of the hire price. Since the ship-owner has to pay the shipbroker, this causes direct cost savings for the ship-owner. As a side or spill-over effect, the ship-owner might be able to lower the charter rate, which would be beneficial for the charterer. On the other hand, this could also result in higher payable loading and discharging rates at the ports. Therefore, the absence of the brokerage fee could also indirectly have positive effects to all involved actors – e.g. also for seaports through higher wharfage and port dues. Accordingly, the exclusion of the shipbroker is adding value for all stakeholders along the maritime supply chain. In particular for smaller and entrepreneurial actors, this enhances competiveness, improves efficiency and enables participation through the enabling adopting of this novel technology due to potentially emerging spill-over effects.

4.2. Cargo import in ports

In the maritime logistics system, three main actors can be pinpointed: (1) shipping companies, (2) ports and (3) freight forwarders (Caliskan and Ozturkoglu, 2018). Hence, the global movement of freight is not realizable without the complementary actors to merchant shipping known as seaports. Seaports are the main hubs for commercial operations worldwide, and thus, each port offers a value proposition to its surrounding region since they provide economic and social benefits (Rodrigue and Schulman, 2013). In fact, seaports are the backbone of the transport network without todays' worldwide economy could not exist in its present form (Funke and Yu, 2011). If all economic activities that depend on the sea would be cumulated, the so-called "blue economy" of the EU is responsible for about 5.4 million jobs and a gross value added of almost 500 billion EUR per year (European Commission, 2017). 74% of goods imported and exported, and 37% of exchanges within the EU transit through seaports (Pastori, 2015). In 2017, almost four billion tonnes of cargo and 415 million passengers passed through the 1,200 European seaports (Eurostat, 2019a, b).

Accordingly, in order to manage the huge freight and passenger demand, the necessity to enhance efficiency in the shipping and port industry increases steady. Especially for port logistics, a safe and reliable data flow is crucial for efficient processes – in particular, when different cargo types shift between distinct transport modes. In order to achieve a smooth operational process flow, real-time data and open data access for all involved parties is essential. Nevertheless, in practice, many port processes are still quite old fashion, which for instance is mirrored by information exchange via telephone or physical paper documentation and forwarding. This is especially true for small and medium-sized seaports that have a common and high interest in digitalisation issues, but among other things are regularly not able to secure financing for their sustainable and competitive development and that are often neglected by scientists and policy makers on EU, national, regional or even local level (Philipp *et al.,* 2018; Rozmarynowska and Oldakowski, 2013).

The usage and implementation of blockchain technology in the frame of port logistics bears the potential to facilitate the transition from a paper documented process management to a digitalised and more secured one by validating and storing each action or transaction, respectively, in the chain of blocks. Accordingly, the optimisation of the financial, cargo and information flow within port logistics through blockchain and smart contract applications exhibit great potentials, even in small ports with less financial resources. To showcase the advantages that arise from a blockchain and smart contract usage in the immediate port sector, the possible implementation of these novel technologies has to be demonstrated and compared with the current situation. Therefore, building upon the findings from the EU-project Connect2SmallPorts, in the following, the case study of the seaport of Wismar in Germany is used as an example.

Wismar seaport in the sense of the analogy of the TEN-T is a comprehensive port and can be classified according to its characteristics as a medium-sized seaport. The geographical position of Wismar seaport fosters mainly the north-south traffic of cargo between Central Europe and Scandinavia. Nevertheless, the site factor also leads to the primary focus of collection and distribution of cargo flows that can be traced back to the east-west connection to the Baltic States and Russia. Wismar seaport is specialised in handling and storing bulk and break bulk cargoes like wood logs and forest products, metals and scrap, building material, salt and fertilizers, as well as project cargo. Its port logistics for energy sources like wood pellets and wood chips represents an important link in the biomass value chain, whereby the seaport is active in both import and export of the related raw material, which at the same time classifies his leading role in the Baltic Sea. Hence, Wismar seaport is an important partner of many sawmills across Europe. However, especially the local timber cluster in the near proximity of the port and in the adjusted hinterland plays an important role for the seaport; and vice versa the port for the local and regional industry and economy. Since for the seaport and the local timber cluster, the import of raw materials – here in particular wood logs – from Scandinavia has a high relevance, in the following, the cargo import case is analysed more detailed. As indirectly and abovementioned in the previous case study, the cargo import case involves many different actors comprising intermediaries like port agents and shipbrokers as well as freight forwarders; ship-pilots; tug masters; inshore pilots; port office and/or authority; terminal/port operators; customs; harbour police; ship owners and/or shipping lines; companies of different transportation modes; insurance companies; banks; customers or cargo receiving companies; and other supply chain stakeholders.

Upon a vessel moors at the quay in the seaport, all cargo-related files are processed by the port agent. Thereby, the necessary information that are usually recorded on physical paper documents (e.g. bill of lading, etc.) are forwarded to the comprehensive INPLAN Port Management System at Wismar seaport. INPLAN eases among other things the forwarding of relevant data and information to the majority of process-involved stakeholders and thus, supports the handling of the respective cargo. Nevertheless, the two main pitfalls are that firstly, the entire operation process flow of the port is not covered and monitored by the system; and secondly, not all internal and especially external stakeholders are directly connected to the system. Consequently, the communication between all involved parties is not optimal enabled and in many cases inefficient through outdated channels leading to the presence of fragmented databases, slowdowns of the process flows and an underperforming supply chain (Prause, 2014).

In the course of a conducted potential analysis of a possible permissioned blockchain implementation, it was derived that the technology fosters the data exchange under the involved parties in the entire process. All relevant cargo-related information can be stored on the ledger of the blockchain once the corresponding participants have approved the uploaded documentation or data, respectively. At the same time the use of the ledger of the blockchain guarantees access to the data and in some cases filtered information at all times and in real time for all participants – including also external stakeholders – if permission is granted. Next to the data reading permission, specific parties can be additionally equipped with a data writing permission. Thereby, data security is ensured through the hashing as well as validation and verification mechanisms that are applied in the course of the creation of blocks to the chain. Next to the hashing and consensus mechanism, all participants receive a copy of the ledger, which jointly secures data integrity in a comprehensive manner and thus, prevent fraud and tampering as well as fosters trust among all involved parties. Overall, the blockchain implementation could streamline in particular the information flow and decreases transaction costs, and thus, the total transportation costs. Furthermore, the implementation of IoT sensors with a direct linkage to the blockchain could provide the distributed and decentralised network with real-time data at all times about the cargo condition and location. For instance, nowadays, especially wood logs are already secured after deforestation by GPS trackers against theft. Thanks to a GPS tracker, which is located in the wood log, it is always possible to trace where it is. Through this, especially the cargo process flow can be optimised due to provided additional cargo-related information that support cargo handling activities and immediately indicate the need for action in case of cargo quality impairment by additional sensor integration (e.g. humidity sensors). Therefore, fewer personnel for quality control checks is required, and error identification in real-time is ensured, which leads to a speed up detection of error causes as well as faster and more efficient countermeasures that can be earlier performed, which heavily saves costs. Accordingly, this is a first step towards automation of the entire port logistics process.

Moreover, by using smart contracts, the automated check of actions and transaction is realised, which leads to a stronger integration of financial service providers into the supply chain. In addition, the payment approval of transactions can be automatically triggered in case of the fulfilment of pre-defined actions. This would improve on a first glance especially the financial flow of the supply chain. However, since all three flows (i.e. information, cargo and financial flow) exhibit interrelations, and thus, are dependent from each other, the comprehensive optimisation of the entire process through the blockchain and smart contract applications forms the real power and synergetic added value of the technology implementation towards a fully automation of port logistics processes. This is also facilitated through the absence of information intermediaries like the port agent or at least lower manual works and responsibilities that are currently covered by the port agent, since all relevant data is directly shared among the distributed and decentralised network of stakeholders, which streamline the overall port logistics process flow and reduces the total supply chain costs. The implementation of blockchain and smart contract solutions break down the central control and information system architecture, and by doing so, in the frame of port logistics processes, fosters existing as well as novel entrepreneurial collaborations of different actors in the comprehensive port environment and along the supply chain. This is especially interesting and beneficial for SMEs due to low participation costs after established blockchain platform and connected smart contract applications.

From comparable studies (Prause, 2018), we can assume a reduction of administration costs of about 2% of total costs induced by the implementation of a blockchain smart contracting system. In addition to that, shorter process times generate additional cost savings. Moreover, as shown in the previous case study, in the course of charter-party contracts for maritime freight transports, smart contracts further encase the potential to replace intermediaries like shipbrokers, which is value adding for all involved supply chain actors (i.e. also for ports) due to spill-over effects. Since within voyage charters the commission of the shipbroker may vary between 1 and 5 % of the gross freight, and in the frame of time charters, the brokerage fee amounts typically 2.5 % of the hire price for the ship; the overall administration cost savings for a seaport like the medium-sized one of Wismar that are attributable to a potential blockchain application including smart contracts amounts at least 4 to 5 %. In addition to that, the possible replacement of further information intermediaries like port agents or at least lower manual works and responsibilities that are currently covered by the port agents, less needed personnel for quality control checks, ensured cargo tracking and tracing, as well as earlier countermeasures in case of detected cargo quality impairments in real-time through integrated IoT devices, sensors and trackers in the operative port processes can generate additional direct cost savings. Accordingly, once again it can be derived that the implementation of a blockchain smart contracting system and thus, especially the exclusion of information intermediaries is value adding for all stakeholders of a supply chain. In line with the previous case, also this case study of a cargo import case highlights that in particular for smaller and entrepreneurial actors the implementation of a blockchain smart contracting system fosters competiveness, increases efficiency and facilitate participation through the enabling adoption of this new technology due to arising lower total supply chain costs.

5. Conclusion

Smart contracts as transactional scripts on the top of the blockchain technology that both have far reaching potentials to ensure disintermediation in maritime supply chains comprising the capability to reduce transaction and enforcement costs. The research revealed that smart contracts and blockchain technology ease entrepreneurial collaborations of cross-organisational business-processes that are distinguishing for smart supply chains.

Especially, the presented case study on macro-logistics level – here: charter-party contracting process within a single voyager in the break-bulk market – showcased the potentials of the blockchain technology and smart contracts to simplify the business processes in the freight market with increased efficiency. All identified aspects in the course of the optimised process flow decrease costs due to shorten process time and lower manual works. Additionally, the potential exclusion of intermediaries (here: shipbrokers) is in particular value adding for smaller and entrepreneurial actors, since their competiveness and efficiency may be enhanced and participation safeguarded through the enabling adoption of this novel technology due to the emergence of spill-over effects.

Specifically, the case study on micro-logistics level – here: the seaport of Wismar and the related cargo import case – highlighted the potentials of the blockchain technology and smart contracts to simplify the port logistics processes with increased efficiency. Thereby, the benefits of an integration of a blockchain smart contracting system in the ecosystem of port logistics are manifold. For example, by using a blockchain platform for a comprehensive and distributed data and information storing and sharing, and smart contracts for automatically executing specific actions and transaction, as well as with support of IoT devices, sensors and trackers, the entire cargo flow in the port area becomes trackable. This can be regarded as an essential development step towards a partly or fully automated operational process flow, which is crucial for the envisaged objective to become a "smart port". Thereby the IoT devices and sensors deliver the needed information for the smart contract applications, whereby the generated IoT real-time data is stored on the blockchain and thus, visible for all involved network participants. Moreover, especially the incorporation of GPS or other tracking systems and sensors encourage this desired development towards a smart port.

Moreover, based on both case studies, it can be concluded that higher flexibility is given for relevant data sharing, since blockchain represents an open platform that is accessible for everyone who shows interest in participation with low entry costs. Through this, the common platform can replace historically grown incompatible systems of different internal and external business entities. Vice versa, this supports a better supply chain integration of all actors.

The common ledger storing procedure ensures real-time and all time distributed network access and information retrieval for all involved parties. Accordingly, no physical documents are needed and each authorised party is able to sign digital with a private key, verify data and fetch copies. Within a permissioned blockchain, it becomes feasible to specify the entree and alteration rights as well as proof of personal identification. Moreover, in a permissioned blockchain, some information can stay private or can be shared in a filtered form, which prevent a potential data flooding.

As a side effect simultaneous file work and a transparent process tracking is always ensured. Generally, through blockchain implementation, all information are decentralised and distributed secured, fraud-resistant, irreversible, steady verifiable, retraceable and always retrievable. All these features increase trust under the authorised network participants and enhance efficiency and flexibility of all process flows (cargo, financial, information).

Smart contracts are able to automatically create and distribute important documents (e.g. charter-party contract, bill of lading, etc.). Therefore, also the auditing process of documents and relevant external data that is provided by IoT sensors and trackers is automated by smart contract applications. Through the programmed processing of this data, final calculations can be automated, too. This automated billing represents a fair and trustful procedure of expenditure calculation and financial transactions.

All these identified advantages that arise from the introduction of a blockchain and smart contracting system decrease costs, which can be traced back to streamlined process time and less manual actions (e.g. cargo quality checks, information auditing procedures, physical paper and document forwarding via courier, etc.). In addition, especially the reduction or elimination of information intermediaries is beneficial for small and entrepreneurial actors, which fosters their competiveness and process efficiency. This is, because they face lower transaction costs and low entry barriers induced by disintermediation. This illustrates that smart contracts and blockchain in the areas of maritime supply chains support the integration of entrepreneurs and SMEs into trans-national maritime value and supply chains by reducing high entry barriers and by weakening the dominating position of big players.

Future research activities should have a deeper look on the legal aspects that must be overcome by introducing blockchains and smart contracting systems in maritime supply chains and in port logistics, as so far they have not been discussed in this research study. At the same time, this represents a general limitation of the current research. Moreover, since the research on smart contracts and blockchain technology in the nexus of maritime logistics sector, and in particular in the context of small and medium-sized seaports have not sufficiently investigated so far, a methodological limitation of the present research study is obvious due to lack of prior research studies on the topic. On the other hand, this represented a clear research gap that needed to be closed. Therefore, the addressed research field of the current research 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 maritime supply chains and particularly in the context of small and medium-sized ports.

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Blockchain for LBG Maritime Energy Contracting and Value Chain Management: A Green Shipping Business Model for Seaports

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Abstract **– To reduce emissions in the maritime transport sector, the International Maritime Organisation (IMO) follows a global clean shipping strategy. Among the different directives of IMO, currently especially the sulphur emission regulations pose challenges for the shipping industry. Related to this are the established Sulphur Emission Control Areas (SECAs) and the introduced global sulphur cap. To comply with the sulphur restrictions, according to the present technological state of the art, ship-owners have three options for their existing fleet: the installation of emission abatement technologies, the switch to low sulphur fuels, or retrofitting for the usage of alternative fuels. Regardless which option is favoured, most often selected solutions still depend on fossil fuels. The reasons for this can be traced back to the fact that supply of biofuels is not ensured in ports and generally seen as no profitable solution. This paper develops and examines an innovative business model with a special focus on liquefied biogas (LBG). The study bases on collected qualitative and quantitative data, which was used by applying the Business Model Canvas. The results will highlight that the business model bears the potential to promote LBG supply. Next to this, the research will show that blockchain and smart contracts are able to foster the implementation of the business model and optimisation of value chain operations. Lastly, economic advantages were highlighted within a case study that refers to the seaport Karlskrona in Sweden and the RoPax ferries from Stena Line that travel back and forth to Gdynia seaport in Poland.**

Keywords **– Business model innovation; digitalisation; emission reduction; global sulphur cap; LBG "Liquefied Biogas"; LBM "Liquefied Bio-Methane"; SECA "Sulphur Emission Control Area"; small and medium-sized seaports; smart contracts**

1. INTRODUCTION

Seaports are the backbone of the transport network without the worldwide economy could not exist in its present form [1]. Concerning Europe, 74 % of goods imported and exported, and 37 % of domestic trade is handled by ports [2]. In 2017, about four billion tonnes of freight and 415 million passengers passed through the 1,200 European ports [3], [4]. Furthermore, approximately 3 million people are employed directly or indirectly in ports across the EU Member States [5].

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According to the International Transport Forum Forecast of the OECD [6], waterborne transport worldwide will grow by 327 % until 2050, producing 238 % more CO_2 emissions. In Europe, it is expected that freight volumes will increase until 2050 by 216 % – with additional 174 % CO_2 emissions. Therefore, it can be assumed that there will be an enormous shift in commodity transportation [7]. This will extremely affect maritime and inland ports. Particularly in the case of small ports, harsh environmental, competitive and operational pressure is expected. Small ports, especially in the Baltic Sea Region (BSR) which represents a flagship region in Europe [8], [9], suffer from out-dated infrastructure, missing smart specialization, inadequate investments, and the absence of new business models that could contribute to blue and green growth [10] – as it is requested in the European Commission's guidelines (e.g. [11]).

The situation of ports in the BSR is even more challenging, due to the issued directives from the International Maritime Organisation (IMO) [12]. To ensure a sustainable reduction of emissions from shipping, the IMO follows a long-term global clean shipping strategy [13]. Thereby, in particular the sulphur emission regulations pose challenges for the shipping industry – namely the established Sulphur Emission Control Areas (SECAs) that are enacted in the IMO MARPOL Annex 2, and the introduced global sulphur cap [14]. SECAs exist in the BSR, North Sea and English Channel as well as along the US American and Canadian coastlines [15]. Similar SECA directives for shipping are the Chinese regulation for coastal waters, which entered into force in 2016, and the EU directive 2005/33/EC [16]. According to the latest gradual adjustment, from 1 January 2015, in SECAs, fuel for ships is not allowed to have a sulphur concentration (% w/w) above 0.1 %. Next to this, on 1 January 2020, the renewed global sulphur cap entered into force, which stipulates to use fuel for ships with no more than 0.5 % (i.e. worldwide, outside of SECAs) [14]. Thus, the ease of use of heavy fuel oil (HFO) do not comply with these emission restrictions any more. By taking into account the current technological state of the art, ship-owners have three options for their existing HFO fleet in order to comply with these sulphur restrictions: the installation of emission abatement technologies like scrubbers, the switch to expensive low sulphur fuels (inside SECAs: low sulphur marine gas oil – LSMGO, ultra-low sulphur fuel oil – ULSFO; outside SECAs: very low sulphur fuel oil – VLSFO), or retrofitting for the usage of alternative fuels (e.g. liquefied natural gas – LNG) [17]. Regardless, which option is favoured, selected solutions usually still depend on fossil fuels. Thereby, the majority of ship-owners, who primarily operate in SECAs, switched to LSMFO and ULSFO, which – compared to LNG – are more expensive, but currently fulfil the requirements of the emission regulations and do not require comprehensive retrofits. This compliance option is also fostered by a general low oil price, since 2014 [18]. Moreover, another reason for low utilisation of biofuels that comply with these emission directives can be traced back to the fact that biofuel supply at competitive market prices is not ensured in ports and thus, often seen as too expensive solutions. In addition, supply of alternative fuels is associated with high investment costs for new infrastructure in seaports [16].

Further challenges, combined with additional investment needs arise from the digital transformation in the maritime industry [19], [20], which must be coped by small ports as well in order to remain competitive. According to Philipp et al. [10], [21], [22], small seaports in the BSR have a high interest in digitisation, but often do not have the necessary skills and capabilities as well as knowledge regarding the already existing wide range of ICT solutions (Information and Communications Technology) or current trends like Blockchain, Industry 4.0 and IoT (Internet of Things) – including the resulting potentials and opportunities. However, despite the lack of know-how, these framework conditions do not only pose risks, but can be seen as development opportunities for smaller ports, too. For example, digitisation in the maritime logistics sector bears the potential for the creation of new business models. Moreover, scientific studies have shown that especially in the context of Industry 4.0, small and medium-sized enterprises can take advantage (e.g. [23]), which on the other hand should also apply to small and medium-sized ports.

Against this background, the research objective of the present study is to develop and examine an innovative business model for regional ports with a special focus on liquefied biogas (LBG) in order to promote supply and utilisation of biofuels and renewable energy. Thereby, the present study refers among other things to the field-to-ferry concept from the GoLNG project and the Maritime Energy Contract (MEC) model, which was theoretically proposed for fuel producers by Olaniyi *et al*. [13], [24], [25]. These models will be adapted to regional seaports, which ensures a more realistic case, due to the fact that the port authorities and/or operators are – next to policy makers – the key players for the transition towards a sustainable biofuel supply and utilisation, as they are the decision makers for the needed bunkering infrastructure and suprastructure developments in the seaports. Furthermore, in the frame of an LBG value chain, traditional fuel producers are usually superfluous. The research bases on collected qualitative and quantitative data that was compiled by a desk research as well as expert interviews, and subsequently used in the frame of the applied Business Model Canvas from Osterwalder and Pigneur [26]. The study addresses the research question how the actions and transactions can be controlled between small and medium-sized ports and ship-owners as well as other potential stakeholders, plus which advantage and added value may be achieved through entrepreneurial collaboration between the key parties. The research results will showcase that the elaborated business model bears the potential to promote LBG supply, as well as that blockchain and smart contracts are enabler for optimised value chain operations and at the same time facilitate the implementation and functioning of the LBG MEC business model. Lastly, a comparative analysis with ULSFO was carried out in the frame of a case study in the medium-sized seaport Karlskrona (Sweden).

The paper is structure as follow: In the second chapter, the theoretical background is given, concerning the MEC and field-to-ferry concept, LBG as an emission compliance biofuel for ships, blockchain and smart contracts, as well as the Trans-European Transport Network (TEN-T) in order classify the European ports and to point out potential financial support schemes for infrastructure developments. Afterwards the used methodology is set out. Building upon this, the research results are showcased, whereby the article rounds up with a discussion and conclusion.

2. THEORETICAL BACKGROUND

2.1. Trans-European Transport Network and Port Classification

The European guidelines for the development of the TEN-T have identified 329 key ports that will become part of a unified network, which will boost growth and competitiveness in Europe's Single Market [27]. The TEN-T will be double-layered; on the one hand, it will consist of a comprehensive network and on the other hand of a core network. According to the corresponding European guidelines, the core network shall be created by 2030 and the comprehensive network by 2050. Inside the core network, nine corridors are planned. These corridors will be multi-modal and shall improve cross-border links (road, rail, waterways) within the European Union [27]. Thus, it is possible to subdivide ports into core ports and comprehensive ports with regard to the identified key ports in the sense of the TEN-T. According to Philipp et al. [10], core ports represent large ports, while the comprehensive ports are medium-sized ports. Vice versa, small ports do not belong to the TEN-T. In order to reach this ambitious objective – developing an integrative Trans-European Transport Network (TEN-T) – the European Commission has launched the financial instrument "Connecting Europe Facility" (CEF)[†]. The CEF provides around € 24.2 billion for the current planning period 2014 to 2020. This budget is provided for the expansion of transport infrastructure, and thus, among other things contributes to meet the infrastructure requirements in conjunction with the development of the hinterland of the selected seaports [28].

2.2. Liquefied Biogas as an Emission Compliance Biofuel for Shipping

Just a few studies record approaches on the usage of LBG in the maritime sector. Similar as liquefied natural gas (LNG), the main energy carrier in LBG is methane [29]. However, the reason why LBG is a biofuel or renewable energy source is the fact that the methane is produced from biomass, that is biogas, either by anaerobic digestion or by gasification followed by methanation [30], [31]. Hence, when biogas is upgraded in order to produce fuel, it is often labelled as bio-methane [32]. Biogas or bio-methane can be liquefied to LBG or liquefied bio-methane (LBM) in the same way as natural gas to LNG [30]. LNG and LBG are nearly identical. Thus, using LBG instead of LNG in ships does not pose any additional technical problems [33]. In this context, it needs to mentioned that there exist also blended fuels on the market (e.g. mixture of LBG and LNG), which are often labelled as biofuels, too. However, in the frame of the present study, whenever LBG is mentioned, it is considered that it is produced to 100 % from biomass and thus, represents a "real" biofuel (i.e. not blended with fossil natural gas – LNG). Following the study from Bengtsson *et al*. [30], LBG as a fuel for ships has the best overall environmental impact – concerning acidification, eutrophication, human health damage of PM_{10}/human toxicity and photochemical ozone formation potential, compared to LNG, HFO, MGO, rapeseed methyl ester (RME), etc. This is mainly caused by lower emissions of NO_x during combustion in engines. Moreover, they concluded that LBG is better than LNG due to its lower life cycle emissions of greenhouse gases (GHG). Comparing it with marine diesel oil (MDO), the switch to LBG would cut GHG emissions by 75–98 % – with assumed zero CH_4 slip [33]. In addition, MDO's total acidifying emissions are almost double compared to LBG. Furthermore, particulate matter (PM) emission from LBG is 80 % lower than in case of MDO. This is deeply rooted in the fact that LBG has a low sulphur content and simple fuel molecule, which burns with low soot and PM formation [33], [34]. Moreover, as stated by Spoof-Tuomi and Niemi [33], the combustion of liquefied bio-methane (i.e. LBG) exhibits a neutral recirculation loop for CO_2. Hence, LBG has the potential to reduce significantly the impact of shipping emissions on local air quality. To sum up, LBG is an attractive low carbon alternative [33], that matches the strict SECA regulations as well as up-coming Nitrous Oxide Emission Control Area (NECA) requirements in 2021 [7], [35]–[37].

[†] The CEF clearly describes which measures and projects are promoted and to which extent. Studies on all transport modes are subsidized with 50 %, whereby traffic management systems, new technologies and innovations are supported with 20 % of the investment costs. In the case of construction projects, the funding rates are not defined explicitly and thus, can differ. The highest funding grants are possible in the case of waterway and rail routes with up to 40 % [28].

2.3. Maritime Energy Contracting and Field-To-Ferry Concept

Energy contracting models are well-known from the real estate or housing sector [38]. Especially in system-relevant buildings (e.g. hospitals), they play an important role, since secured energy supply at all times is crucial [39]. Next to the Energy Performance Contracting (EPC) model, especially the Energy Supply Contracting (ESC) approach is used in practice. The ESC model provides the necessary basic energy and is used for services that lack capital investments [24], [39]. The idea to adopt the ESC model in the maritime sector is quite new and had been firstly proposed by Olaniyi *et al*. [13], [24], [25]. Nevertheless, in their studies the crux of the matter were the fuel producers, who should apply the developed MEC model for either an efficient supply of LNG to ship-owners or a wide usage and installation of scrubbers on board of ship-owners' vessels. Thereby, the used comparison fuel was MGO, which does not comply any more with the corresponding sulphur emission regulations. However, especially by considering the LNG case, next to an exclusive focus on the downstream value chain, they do not take much regard to the ports, where the fuel supply to the vessels takes usually place. In this context, it must be clarified that not the fuel producers are empowered to decide whether a new bunkering possibility will be implemented in a harbour – such decisions are made by the port authorities and/or operators or corresponding municipalities in smaller ports. Thus, next to policy makers, the key players for an efficient transition towards supply and utilisation of alternative fuels like LNG, LBG, etc. are the seaports. Moreover, for the production and supply of biofuels like LBG, traditional fuel producers that typically focus on fossil fuels are not (necessarily) needed; as shown by the field-to-ferry business concept, which was elaborated in the frame of the GoLNG project and theoretically proposed for the Danish island and municipality Samsø. However, this study lacks of economic reasoning and thus, highlights only non-monetary environmental and social benefits of using LBG as a fuel for shipping [40]. Among other things, this can be traced back to the problem to supply LBG at a competitive supply price in comparison to LNG. Hence, it must be clarified that without any economic advantages that result in reliable incentives, the transition from fossil fuels and resources to ecological sustainable emission compliance biofuels and renewable energy will not be safeguarded. Accordingly, if subsidies are not granted for biofuels like LBG, a transition towards fossil free shipping (i.e. green shipping) is less likely.

2.4. Blockchain and Smart Contracts

Blockchains are distributed ledger systems that ensure via alphanumerical code and private key safe execution of transactions in a network with potentially untrusted participants. The distributed virtual ledger system can supplant physical documents as well as signatures [41]. However, one of the most important characteristics of blockchain is that for the cryptocurrency exchange intermediaries become superfluous, which automatically leads to the emergence of a decentralised trusted network [42]–[46]. Hence, through blockchain application the up-to-date information accessibility can be ensured at all times, whereat transaction and intermediary costs decrease, which is especially value adding for SMEs and entrepreneurs [47]. Thus, as highlighted by Philipp *et al*. [48], the blockchain technology facilitate entrepreneurial collaborations in trans-national supply chains. An advancement are smart contracts that build up on the blockchain technology and represent transactional scripts or protocols that include terms and conditions of contracts [43], [46], [47], [49]. Embedded through digital codes with software on the blockchain platform, they automatically process the negotiated contract conditions to which all involved parties previously agreed [44]. In addition, they are empowered to perform reconciliations that are self-executable induced through new transactions as well as updated or uploaded data and documents on the blockchain ledger – e.g. via IoT applications [41]. Hence, if all pre-defined terms and conditions are fulfilled, smart contracts automatically trigger a certain number of transactions or actions [50]. Therefore, smart contracts are able to read from and write on the blockchain [41], [48], [51]. Since they are implemented on the blockchain platform, smart contracts face the same high data security characteristics – e.g. protection against distortions, revisions and manipulations as well as deletion [44]. Nevertheless, the main advantage can be seen in the elimination or reduction of intermediary levels (e.g. third parties, middlemen, brokers or agents like governments, banks, lawyers, etc.) in diverse business activities, which fosters the efficiency and redesign of complex business structures that are characteristic for supply and value chains [41], [48]. To sum up, the unique characteristics of the blockchain technology and especially the possibility for the execution of smart contracts have promoted the ideas for even greater application areas in different markets that go far beyond the financial sector.

3. Methods and Methodology

In the framework of the given study, the theory-based and practice-related research has been applied building upon empirical data from expert interviews, case studies, observations and practical findings that have been collected and produced in the frame of the GoLNG and the ongoing Connect2SmallPorts project. The Connect2SmallPorts project focusses 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 South Baltic Sea Region, with a specific emphasis on digitalisation issues in small and medium-sized seaports – particularly blockchain and IoT. The project is part-financed by the ERDF as it is implemented in the framework of the INTERREG V A South Baltic programme. In contrast, the GoLNG project focalized on the implementation of the EU Clean Fuel Strategy and the EU Directive on Deployment of Alternative Fuel Infrastructure through technology and knowledge transfer in LNG related business activities and improvement of the LNG value chain in the BSR, whereby also the possibility of LBG production and distribution provided in the integrated LNG value chain was analysed (LBG sustainability for LNG infrastructure). The project was also part-financed by the ERDF, since it was implemented in the framework of the INTERREG V B Baltic Sea Region programme. Through active collaboration in the GoLNG project and leadership in the Connect2SmallPorts project, the researcher received access to a wide range of data and insights on the research topic, which was crucial and the stepping-stone for the current research study.

Data collection activities comprised initially the search, identification and analysis of secondary data that was gathered through the study of fuel market reports, topic-related policy regulations and guidelines, scientific literature and websites regarding up-to-date and historical spot prices. In addition, structured expert interviews with top-level managers from Karlskrona seaport were conducted in January 2020. The interviews lasted about one hour and were recorded and transcribed. The interview analysis was conducted according to Kvale [52] and Miles *et al.* [53].

The field-to-ferry-concept from the GoLNG project and the MEC concept from Olaniyi *et al*. [13], [24], [25] are used as a baseline for the development of the new LBG MEC business model. For the creation of the business model, the Business Model Canvas from Osterwalder and Pigneur [26] was applied. For the design, discussion and presentation of an innovative business model, Osterwalder and Pigneur [26] in their Business Model Canvas refer to nine basic building blocks: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, cost structure. All these nine building blocks need to be described and intertwined with each other in order invent a new competitive business model. Thereby, for presenting the monetary aspects, a comparative analysis with ULSFO was carried out. For this, a case study approach according to Yin [54] was used to exemplify the operating principles of the business model. The case study refers to the comprehensive seaport Karlskrona in Sweden and the RoPax ferries from Stena Line that travel back and forth to Gdynia seaport in Poland (i.e. SECA in the BSR).

4. Results

Competition in the shipping sector is steady increasing due to decreasing freight rates and volumes of passengers. Hence, ship-owners – especially those, who are mainly active in emission control areas through Short-Sea-Shipping (SSS) – are under financial pressure and thus, fear retrofits of vessels' engines for complying with emission regulations, since they are associated with high investment costs and risks. To tackle this issue, in the course of the new business model, the port will henceforward provide LBG to ship-owner's vessel (i.e. energy/fuel supplier role) and will become responsible for arranging the retrofit of the vessel towards a dual fuel engine that is also able to combust LBG, as well as the subsequent maintenance (i.e. energy/fuel service role). As a result, the emission compliance costs for the ship-owner decrease and the business scope of the partner port will be enlarged through new additional service offers. Next to the resulting costs for a steady LBG supply, engine retrofit and regular maintenance, the envisaged contract (i.e. LBG MEC) will also consider an adjustment premium for the port as energy and service provider.

4.1. Value propositions

The superordinate value proposition is the significant contribution to the reduction of emissions as well as the sustainable switch from fossil to biofuel or renewable energy, respectively. On the one hand, in the context of the ship-owner, this means, receiving access to emission compliance fuel, at reduced or eliminated risks, investment (retrofit) and operational costs (fuel and maintenance costs). This is, because the port will become responsible for arranging the retrofit towards a dual fuel engine that is also able to combust LBG. Hence, capital investment and associated risks are taken over by the port. Furthermore, under the premise that LBG as a biofuel for ships can be supplied at approximately the same price as LNG, it is much cheaper as other usual SECA compliance fuels like LSMGO and ULSFO. This aspect can be highly beneficial, since 50 to 60 % of voyage operational cost are attributable to fuel costs [55]. Accordingly, the port guarantees the steady fuel supply during the contract period. Moreover, operational costs decrease even more, since responsibility for arranging regular engine maintenance will be taken over by the port as well. Thus, port's value proposition to the ship-owner can be regarded as an "all-round carefree package".

On the other hand, the port, further potential customers and other stakeholders in the local or regional costal area benefit from fewer emissions, which contributes – for instance – to a lower occurrence probability of respiratory and cardiovascular diseases, and thus, adds substantial value to the society – but also to the environment in general.

4.2. Customer Segments

The main customers are ship-owners, shipping companies or ship-operators, who have to show compliance to IMO emission regulations and fear retrofits due to high capital investments as well as related risks or uncertainties, respectively.

There exists also the potential to extend the LBG MEC business model to other transport modalities in the near proximity of the port. For instance, LBG or compressed biogas (CBG) can be used as well in the road transport sector (e.g. trucks and busses). Furthermore, it is also possible to expand the scope of customers to the industrial sector (i.e. companies with high-energy demand) and local or regional gas grid operators in the catchment area of the port in order to serve the energy demand – e.g. in the municipality. For several years, there is an increasing environmental awareness in society, so that private households are willing to pay for green gas.

4.3. Customer Relationships

The port and the ship-owner will become close business partners with a strong relationship that will be contractually fixed. The "all-round carefree package" includes and enables (1) a guarantee for steady LBG supply, (2) takeover of responsibility for arranging dual fuel engine installation and regular engine maintenance, (3) risk absorption, (4) added value through emission compliance solution, (5) renewable fuel branding (i.e. marketing), as well as (6) expertise and consultation regarding planning and execution of the MEC project. The ship-owner is the main costumer in the LBG MEC business model. Thus, the port has a special interest to optimally satisfy the needs of the ship-owner. Moreover, since the retrofit is the investment of the port, during the contract period, the legal ownership regarding the dual fuel engine belongs to the port, whereat the ship-owner receives the economic ownership. Nevertheless, as soon as the contract period ends, the legal ownership goes over to the ship-owner, too, whereby in case of an open residual value, the ship-owner has to arrange a corresponding one-time compensation payment – usually whenever the contractual relationship ends prematurely. Hence, regular exchange of information as well as monitoring activities must be ensured. This includes regular inspections and maintenance measures in order to secure long-term and perfect engines operations that are initiated and arranged by the port in order to optimally fulfil the needs of the ship-owner as a primary customer (i.e. securing ship-owners' primary business operation – shipping). Thus, the port has the responsibility to keep under constant review all engines – i.e. control function. All these aspects must be negotiated, defined and agreed between both contractual parties prior the contract is closed (i.e. signing process conducted by the contractual parties).

In the potential event that the LBG and biogas clientele will be enlarged over the time to other transport modalities, the industrial sector or gas grid operators, this will be achieved always on a contractual basis, whereby the interdependency and scope of required services define the business relationships.

4.4. Key Partnerships

Next to the ship-owner, who will be the main costumer, there exist different key partnerships that must be established by the port. In order to identify all relevant key partners, two potential cases must be considered: (1) the port focus on the organisation of the downstream LBG value chain, and (2) the port considers to integrate horizontally in the upstream LBG value chain, too.

Initially, in order to kick-start the new LBG MEC business model, the port will focus on the downstream LBG value chain – i.e. primarily on the ship-owners as the main end-users. Accordingly, the port primarily concentrates on the steady supply of LBG to ship-owners' vessels. In this case, the supply of LBG to the port requires a key partnership with a LBG bunker trader (i.e. intermediary – fuel broker) or directly with a biogas liquefaction company, who will be responsible for the overall LBG supply to the port. Since the port will be also responsible for arranging the retrofits towards dual fuel engines as well as the related regular maintenance, an additional key partnership is needed with a shipyard or maintenance company, respectively. Vice versa, all this induces the necessity of additional partnerships with an investment bank and an insurance company.

However, in case of a developed and enlarged group of customers in a maturity stage, a stronger focus on the upstream LBG value chain can make sense. In this case, additional long-term partnerships (e.g. with additional customers – road transport sector, industrial companies, etc.) must be established by the port, whereby other partnerships become superfluous (i.e. reduction or elimination of intermediary levels by the port – replacement). The general upstream LBG value chain as it is shown in the Samsø field-to-ferry case consist of: farming system, biogas plant, biogas upgrading and liquefaction. The major advantages of an integration of the port into the upstream LBG value chain can be seen in higher control, short transportations, more reliable value chain, exclusion of intermediaries, and thus, decreasing transaction and enforcement costs, whereby LBG or biogas can be supplied at lower prices to the end-users. Hence, new key partnerships emerge with the local or regional farmers, whereas also expertise and support through key partnerships with suppliers of biogas plants as well as upgrading and liquefaction technologies is needed (i.e. for the construction project and subsequent plant maintenance activities). Vice versa, previously important key partnerships like LBG bunker trader or liquefaction company become superfluous – i.e. elimination of intermediary levels. On the other hand, this scenario results in high investment costs for the port. Nevertheless, according to the findings from the GoLNG project, the overall investment for the development of the needed infrastructure – comprising biogas plant as well as biogas upgrading and liquefaction facilities – amounts about € 10 million [40]. On a first glance, this amount appears to be high, but considering that this covers the establishment of an entire local or regional LBG value chain, it can be evaluated as low. In addition, national or international subsidies can be used to co-finance this construction project. For instance, according to the CEF (TEN-T), funding rates between 20 to 50 % are achievable [28]. That this is feasible, can been seen in the Frederikshavn case, where Nordliq Nature Energy, Bunker Holding, Kosan Crisplant and Frederikshavn Havn are partners in the consortium behind Nordliq, a liquefaction plant project in the port of Frederikshavn (Denmark) with a targeted LNG production capacity of 50, 100 or 150 metric tonnes per day [40].[‡] This project receives support from the European Commission via the CEF. In addition, for the biogas production, the bio waste from the region can be used as well, which opens opportunities for sustainable and better waste handling. In addition, in case of an existing local or regional gas grid, which was established for suppling natural gas to the surrounding household area and industrial companies, the same infrastructure can be used for the provision of biogas. Hence, a key partnership with the local or regional gas grid operator or owner can be reasonable, whereby also the port can cover its own energy demand. Moreover, as a side effect, the farmers can receive an organic fertilizer after the biogas process. Hence, keeping these aspects

[‡] According to the project in the port of Frederikshavn, LNG will be supplied from the process tanks by tank trucks to the loading points, whereby LNG will be offered to ships and heavy load trucks [40].

in mind, the LBG MEC business model in an enlarged case has the potential to contribute substantial to the creation of a circular economy. Lastly, the business model can contribute as well to the development of a small energy autarkic region as well as the emergence of a green transport corridor.

4.5. Key Activities

In the initial case, the key activities of the port are enlarged through the new biofuel provision (here: LBG) and additional services that refer primarily to the arrangement of the engine retrofit and subsequent maintenance. All these activities must be planned and arranged individually for each vessel – according to the respective ship features. Hence, the port needs to increase staffs' knowledge, skills and capabilities regarding LBG handling and project management. This can be achieved by trainings and seminars or recruitment of new employees with expertise in LBG, whereby also outsourcing is an option. In addition, in order to secure long-term and perfect engines operations and thus, to fulfil optimally the needs of the ship-owner, a regular exchange of information as well as monitoring activities must be performed. Therefore, another key activity can be seen in ensuring a secured data information exchange, by the integration and usage of a suitable technology that is also able to automatically generate contracts and billing with all relevant key partners and customers. Similar as in case of Philipp et al. [48] – who described the integration of a blockchain smart contracting system in the charter-party contracting process – also in the frame of maritime energy contracts, the usage of the blockchain and smart contract technology is reasonable – since the standard MEC is also a contract that can be automated. Moreover, such a solution becomes quite effective through the inclusion by IoT sensors at the ship engines and tanks that permanently monitor the optimal performance and fuel consumption.

In the maturity stage, further key partnerships occur and thus, the scope of the abovementioned key activities will enlarge (e.g. secured data information exchange including automated contract generation to a wider group of relevant key partners), whereat new and additional key activities emerge, too. For instance, one of the new introductory key activities embraces the identification of suitable funding schemes on national and/or international level for the construction project of the local or regional LBG value chain. However, in order to initiate the project, which embraces grossly the phases planning, development and finalisation/launch of operations, the most important preparatory key activity is the generation of public awareness, which implies a comprehensive integrative communication process in the region with all relevant stakeholders. An extensive communication and a public discussion about the project in a reasonable manner are important, since such measures increase the chance of the project to be successful. Next to acceptance by the public, political support is needed for receiving legal permissions.

4.6. Key Resources

By focusing on the downstream LBG value chain, a new key resource is the LBG, which will be provided to ship-owners' vessels. This includes as well the needed fuelling systems for pumping LBG into vessels' tank. Next to this, since the port takes over the investment for engine retrofit, the resulting dual fuel engine plus LBG ship tank including pumping system, etc. will become new key resources, too. Compared to these tangible key resources, the intangible key resources embrace the LBG experts and service personnel in the port, if outsourcing is not considered. Moreover, the blockchain with smart contract applications for secured data information exchange, as well as the IoT sensors at the new dual fuel engine and tank for monitoring purposes represent further intangible and tangible key resources.

If the port considers to integrate into the upstream LBG value chain, the physical infrastructure for the production and bunkering of the biogas and LBG – thus, almost the entire LBG value chain – becomes a new key resource (i.e. especially the biogas plant, biogas upgrading and liquefaction facilities as well as the established bunkering option in the port). In addition, the associated competence in form of staff along the local or region LBG value chain becomes an intellectual key resource, too. Since, this scenario opens also the possibility to sell biogas or CBG to further end-users, these outputs as well as related supply facilities or equipment, respectively, represent further potential key resources.

4.7. Channels

Regarding the downstream LBG value chain, the port primarily concentrates on the steady supply of LBG to ship-owners' vessels. Similar as in the case of LNG, for bunkering and supply of LBG in a port, there exist four general opportunities that cause different investment costs [56]: ship to ship transfer (STS), truck to ship transfer (TTS), terminal/pipeline to ship transfer (PTS), and portable tanks. In the latter case, as soon as the tank is empty, it will be replaced by a full tank; hence, the reception of LBG to the port consists of loading and unloading as well as connection and disconnection of the portable tank system [57]. Especially the TTS and portable tanks options tie up little capital and are suitable for the supply of small quantities of LBG. However, in the initial case, the overall supply of LBG to the port is outsourced. Hence, the port staff is responsible for fuelling the LBG from the bunker option into vessels' tank. LBG distribution and inventory can be monitored automatically through the implementation of blockchain as well as smart contract applications, which additionally bears the potential to eases the management of the value chain. Hence, for enhancing the LBG MEC business model, a blockchain driven smart contracting system is proposed. Through this, the material, information and financial flow of the overall LBG value chain can be improved. The maritime energy contracting process embraces three phases: (1) pre-fixture, (2) fixture and (3) post-fixture.

In the pre-fixture phase, relevant information that is needed from the ship-owner are ship type, size, current engine status, annual runtime and further features of the vessel. A smart contract application can conduct initial calculations for the whole project according to the provided data by the ship-owner about the vessel. Hence, the smart contract application can automatically compute and estimate the needed capital investment for the retrofit towards a dual fuel engine based on the ship characteristics, as well as deliver an answer whether the investment is reasonable due to ships' age, size, available space for dual engine and tank installation, the intended purpose, etc. Additional input data that is needed for the smart contract investment calculation is stored on the blockchain, e.g. price range for retrofits towards dual fuel engine according to different ship types – provided by the shipyard (key partnership). Furthermore, the smart contract application can also predict the needed average regular LBG quantity, maintenance and inspection schedule including potential average costs that occur, as well as the LBG supply price – derived from current data, which can be integrated, stored and automatically self-executable updated on the blockchain ledger in real-time. Building upon this, a kind of pre-contract can be automatically generated by the smart contract application, since the provided data from the ship-owner represents the initial information and pre-conditions that must be reconciled and fulfilled for the aspired development of the LBG MEC.

In the fixture phase, the MEC will be signed by both parties (i.e. port and ship-owner) insofar all contract terms and conditions are negotiated and subsequently agreed. In an optimal case, the MEC contains all relevant information, e.g. details regarding the ship-owner and port, ship details, LBG price (range), expected average fuel demand, inspection and maintenance schedule, quality assurance, interest rate, adjustment premium for the port, contract duration, in case of a fixed route (origin and) destination port(s), payment method, payment terms and details including currency, clauses in case of a potential prematurely contractual ending as well as the corresponding calculation method and procedure of the resulting necessary one-time compensation payment, and other obligations and rules as well as clauses. Therefore, also legal aspects and responsibility in case of unexpected events or in case of non-performance have to be integrated into the MEC. Once the port and the ship-owner have jointly agreed on the rates and terms, the MEC agreement will be fixed through the signing process. This procedure can be automated by a blockchain smart contracting system, too. Norta [58] developed a smart contracting setup lifecycle for negotiation procedures, which can be adapted through reconfiguration and thus, applied in the course of the MEC negotiation process. Furthermore, current data like biogas price, which usually function as input data and a point of orientation, can be automatically integrated in the smart contracting negotiation process. Hence, if all pre-defined conditions are fulfilled (i.e. the smart contracting setup lifecycle for negotiation achieves a concluding outcome), the smart contact application is able to automatically generate the smart MEC, whereby the contract parties can digitally sign via a private key. Thus, the smart contract application replaces the physical paperwork (i.e. multiple versions of files, signatures, etc.), whereat each party can digitally validate files and generate copies. Moreover, the elaborated and fixed MEC as a smart contract is than automatically stored and secured on the blockchain. Accordingly, the smart MEC becomes decentralised and distributed secured, fraud-resistant, irreversible, steady verifiable, retraceable and retrievable at all times for all involved parties during the contract period.

Next to the one-time engine retrofit, the post-fixture phase mainly embraces monitoring tasks. These monitoring tasks primarily refer to the fuelling of the ships (i.e. distribution of LBG) and maintenance. Normally, both processes cause much physical paperwork. For instance, the status information about the regular fuelling operations result usually in the back and forth sending of physical documents and copies between the port and ship-owner (i.e. port staff that is responsible for the fuelling, the ports' controlling department, port/ship agent(s), ship's captain and crew staff, etc.) that subsequently function as important input data for the regular fuel supply billing. However, the implementation of a blockchain smart contracting system with IoT applications can also improve the fuelling as well as maintenance scheduling, since all corresponding information and assisting documents can be uploaded and stored on the blockchain in real-time; and thus become decentralised secured, fraud-resistant, immutable, transparent, permanently auditable[§] and historically retraceable as well as accessible for smart contract applications as well as all involved participants, who have

[§] Smart contracts can automatically perform in real-time auditing procedures in case of uploaded documents and other types of information on the blockchain. This includes as well the automated checking and programmed processing of transactions or other kind of information that occur and at the same time can lead to the fulfilment of specific pre-defined conditions, which induces triggering of further actions or transactions (i.e. if-then-else functions). On the other hand, corresponding users are able to upload data and approve the uploaded documents and information from other entities – if permission or rights are given. Hence, next to data reading permissions, some or all blockchain participants can have a writing permission, too. Security is guaranteed through the hashing as well as validation and verification mechanisms in the frame of regular block creations for the chain. Thus, all or only selected parties receive a copy of the blockchain ledger for auditing purposes. Therefore, data fraud or tampering becomes impossible.

permission. In general, this fosters trust among all involved actors and enhances efficiency of the processes due to a higher flexibility.

Regarding maintenance, recent technological innovations allow for optimised scheduling of activities. For instance, acoustic sensor applications are nowadays capable to show up disturbances in engines operations that are no longer perceptible to human hearing. Hence, engines and pumping systems can be permanently monitored by IoT applications in a much wider frame than current electronics on a usual ship can do. Furthermore, monitoring operations during the voyage over long distances (e.g. from the port terminal) become possible. This ensures that maintenance is induced before a serious problem arises that can lead to reduced performance or in a worst-case scenario to a breakdown. Such applications are summarised under the term "smart maintenance" and are highly value adding due to cost savings – especially in different industrial sectors that are dependent from smooth functioning of machines and facilities at all times. Smart maintenance can cause spontaneous or short-term, but rather small interventions that in total are much cheaper than the overall costs that may arise from a complete production breakdown or performance dropout, which among other things result in shortages and regular more expensive maintenance or purchases of new engines, machines or even complete facilities. Hence, smart maintenance is value adding to customers and guarantee sustainability in resource management, which vice versa protects the environment. To sum up, IoT and smart contract applications feed the blockchain with needed input data and smart contracts process these information and data in order to trigger further transactions or actions – e.g. initiations of spontaneous inspection or short-term maintenance, respectively.

Regarding the fuelling of the ship, the IoT sensor applications on board at the tank can monitor and send the fuel consumption and need in real-time to the port. Furthermore, the delivery of LBG from port bunker to ships' tanks can be also monitored by the blockchain smart contracting system (i.e. controlled distribution). Hence, when the ship is in the port and needs fuelling, the back and forth sending of information, documents and copies for the overall process is not needed any more. Thus, the integration of blockchain smart contracting system bears the potential to foster the establishment of full- or semi-automated LBG bunkering and fuelling operations in the port [56]. Moreover, blockchain and smart contracts enable automatically forecast calculations and the triggering of LBG repeat orders, which secures the avoidance of shortages in supply in the port.

Bearing this latter aspect in mind and transferring it into the context of a potential enlarged case, where either all actors of the value chain participate in the same blockchain (i.e. joint digital infrastructure[**]), or the port considers to develop a local or regional LBG value chain as an integrator, the blockchain smart contracting system is able to optimise the management of the entire chain. With other words, through blockchain and smart contract applications, the upstream LBG value chain nodes and entities can receive real-time information and predictive data about the current as well as expected future consumption or demand of the downstream LBG value chain – including end users. Accordingly, with blockchain smart contracting systems value chain management becomes smarter and thus, more efficient, since resource-optimised production along the whole chain is ensured through automatically generated real-time and forecast data. Thus, over and under capacities can be avoided.

[**] By using blockchain as a joint infrastructure data exchange between incompatible systems is avoided and the data transfer becomes digital and automated, which enables a simultaneous document processing and process tracking and thus, a greater transparency and flexibility as well as streamlined processes, since no back and forth sending of physical documents is necessary.

Moreover, this includes as well the possibility that smart contracts are able to automatically conduct the financial calculations and the related generation of billings and payments, e.g. for the famers, who produced the biomass for the biogas plant, as well as for fuel and energy supply of downstream stages of the value chain or end-users. This is achieved through the underlying blockchain, where the needed input data is available through IoT applications and integrated market data as well as the smart contracts – that include all respective rates, prices, terms, etc. – along the chain. The same applies for the planned or spontaneously induced inspections and maintenance of tangible key resources; or if a contractual relationship with an end-user (e.g. ship-owner) prematurely ends, since the corresponding smart contract application is able to perform automatically the corresponding calculations (e.g. residual value and thus, necessary one-time compensation) and subsequent generation of the billing. Hence, all occurring financial calculations, billings and transactions along the LBG value chain can be automatically elaborated and triggered, if all corresponding pre-defined conditions are fulfilled and thus, all relevant data and information is available in the chain of blocks through uploaded, secured and shared files. As a result, the emergence of objections by the involved parties can be limited due to the decentralised nature of the blockchain and smart contract technology. Accordingly, this procedure guarantees a trustful and fair approach for automated concluding calculations as well as monetary transactions, which decreases costs due to shortened process time and lower manual works. Therefore, it can be stated that blockchain and smart contracts are able to contribute substantial in the pursuit of perfection of material, information and financial flows in supply and value chains.

Nevertheless, apart from all these showcased benefits, in particular the potential exclusion of intermediaries can have far-reaching positive impacts. The formerly given trust through the presence of the intermediaries is compensated by the decentralised nature and further benefits of the blockchain and smart contract technology, which automatically leads to the emergence of trust among all involved users of the digital infrastructure (i.e. blockchain). Through the exclusion of the intermediaries, transactions and enforcement costs decrease which is value adding for the port as an integrator, but also indirectly for all participants in the blockchain network through potential spill-over effects. Especially for smaller and entrepreneurial actors this enables participation [48].

Lastly, for the described purposes, a private permissioned blockchain would be an appropriate solution. This is reasoned by the fact that within a permissioned blockchain, it is possible to clarify access and modification rights of the participants as well as proof of personal identification. Next to this, in a private blockchain, specific transactions or actions can be set as private to certain participants. This can be regarded as a data filter, which ensures that only certain authorised participants are allowed to add, receive or inspect corresponding data and information that is needed for further actions in their area of responsibility [48].

4.8. Revenue Streams and Cost Structure

To exemplify the operating principles of the proposed LBG MEC business model, in the following, the initial case for kick-starting the business model – where the port and ship-owner become close business partners – will be analysed in detail by examining the related revenues and costs. As proposed by Olaniyi and Gerlitz [25] as well as reasoned by the fact that a vessel represents a moveable asset, the nominal contract duration should be about five years, whereby regular audits shall be performed, which may result in necessary contract adjustments. The LBG MEC embraces three parts: (1) LBG baseline price, (2) adjustment, and (3) asset costs (i.e. costs for retrofit towards duel fuel engine and subsequent maintenance).

In order to highlight the different components of the LBG MEC, the case study of Karlskrona seaport in Sweden is used. Karlskrona is a comprehensive port according to the analogy of the TEN-T and thus, the port may receive financial support through the CEF for infrastructure developments in the frame of a potential expansion scenario. On the other hand, this means that the port of Karlskrona can be classified as a medium-sized or regional seaport. In 2019, the seaport handled ca. 450 000 tonnes of freight and 700 000 passengers. Therefore, it can be noted that Karlskrona represents rather a typical ferry port. The single regular ferry route is to Gdynia seaport in Poland. Hence, the ferry operation refers exclusively to the BSR and thus, SECA. The route is operated by Stena Line with the three RoPax ferries "Stena Vision", "Stena Spirit" and "Stena Baltica". The characteristics of the three ships are quite similar, and currently all of them use ULSFO. Each of the three vessels sails about 300 to 350 times per year, whereby one voyage (back and forth) takes ca. 2·10 hours and causes a total fuel consumption of about 53.4 to 62.3 metric tonnes (MT). Stena Line has a high interest in alternative fuels, whereby the company considers especially LBG as the shipping fuel of the future [59]. For the following calculations, it is assumed that LBG is used to 100 % after retrofit, whereby initial calculations refer to one ship.

Regarding LBG baseline price, currently there exist no market data (neither historical nor up-to-date), since the LBG market is not sufficiently developed. Nevertheless, if LBG should become a competitive alternative to LNG, the LBG baseline price has to be approximately the same as for LNG, which can be achieved in the long-term most likely only through subsidies. However, in order to derive an approximate, but reasonable LBG baseline price, the study from IEA [60] is used. According to this study, landfill gas recovery systems (2 000 m^3/h) can produce biogas for less than 3.00 \$/MBtu, whereby upgrading costs amount 2.00 to 4.00 \$/MBtu for facilities that upgrade around 3.5 million m^3 of biogas per year. By taking the average upgrading costs yield total biogas supply costs of 6.00 \$/MBtu, which is equal to 211.86 \$/m^3 (1 MBtu = 0.02832 m^3). However, since liquefaction costs are also unknown, the corresponding finishing factor is deduced from the American export price spread between natural gas and LNG from EIA (Independent Statistics and Analysis – U.S. Energy Information Administration) [61], since biogas can be liquefied to LBG in the same way as natural gas to LNG, which pleads for a similar finishing factor. The resulting average finishing factor for January 2018 is 1.12727.[††] By taking the corresponding dollar exchange rate (€ – \$) at the end of the same month with 1.2413 [62] and the liquid density factor of methane with 0.42 kg/l yields an LBG baseline price of 458.10 €/MT at the end of January 2018[‡‡].

To determine the asset costs, as a starting point, the corresponding data for a general LNG retrofit is used, since LNG and LBG are nearly identical concerning engine's fuelling and combustion, and thus, using LBG instead of LNG in ships does not pose any additional technical problems, which at large pleads for similar costs. According to Balland [63], the

[††] The average price of U.S. natural gas pipeline exports in January 2018 was 3.85 \$/Tft^3, whereby the average price of liquefied U.S. natural gas exports in the same month was 4.34 \$/Tft^3 [61]. The resulting finishing factor is relatively opportune, since the price spread was usually higher during the last decade. However, since the U.S. export LNG price can be also lower than the related natural gas price (e.g. usually between January 2003 to August 2008) [61], the average price spread as of January 2018 was used for the approximation.

[‡‡] Usually the LBG baseline price can be higher; but in some cases also lower, due to volatility in dollar exchange rate and finishing factor (i.e. average price spread factor between LNG and natural gas). Moreover, according to the study of IEA [60], total baseline supply costs for biogas vary according to the used feedstock and technology. Hence, the LBG supply price can be usually higher, but in order to generate a reasonable approximate value for the LBG baseline price and to avoid hypothetical assumptions about possible subsidies that would result in a competitive market price in comparison to LNG, the LBG baseline price was derived as described and set with 458.10 €/MT.

usual total investment costs for a retrofit towards dual fuel engine that is also able to combust LNG (or LBG, respectively) amount about \$ 5 800 000.00 to 6 100 000.00 or € 4 672 520.74 to 4 914 202.85, respectively (by using the dollar exchange rate at the end of January 2018). On the basis of the average total investment costs for the retrofit together with an economic lifetime of 15 years and an interest rate of 6 %, the average annual asset value amounts € 493 537.78. According to the study from Madsen [64], the annual total maintenance and repair costs of comparable ships (i.e. with a dual fuel engine that is also able to combust LNG or LBG, respectively) range between \$ 124 843 to 301 408 or € 100 574.40 to 242 816.40, respectively (by using the dollar exchange rate at the end of January 2018). By taking the corresponding average value of the annual total maintenance and repair costs plus the average annual asset value, the average annual project asset costs amount € 665 233.18. The asset costs are derived from the proportion of the average annual project asset costs at the average annual LBG consumption (i.e. in the latter case: average annual voyages multiplied with the average LBG consumption per voyage). The average annual LBG consumption is 18 801.25 MT. Thus, the asset costs yield 35.38 €/MT.

For calculating the adjustment, the following formula is applied:

$$A_{LBG} = \frac{PAC_{LBG} \cdot \left(0.5 + 0.3 \cdot \frac{CPI_{t=i}}{CPI_{t=0}} + 0.2 \cdot \frac{LPI_{t=i}}{LPI_{t=0}} \right)}{C_{LBG}},$$

where

A_{LBG}	LBG adjustment;
PAC_{LBG}	LBG project asset costs;
$CPI_{t=i}$	Consumer price index at $t = i$;
$CPI_{t=0}$	Consumer price index at $t = 0$;
$LPI_{t=i}$	Labour price index in $t = i$;
$LPI_{t=0}$	Labour price index in $t = 0$;
C_{LPG}	LBG consumption;
$t = i$	Contract point in time;
$t = 0$	Contract starting point in time.

According to the formula, within the adjustment, the costs of the asset, inflation and changes in salary are considered [13]. In respect of the weighting factors, it can be stated that 50 % of the adjustment is stable, 30 % depends on the inflation (consumer price index), and 20 % depends on the development of the salary costs (labour price index) [24].

In the frame of the example case, the adjustment is calculated for September 2018. Hence, by taking the CPI of Sweden at the end of January 2018 (322.51) and September 2018 (331.14), as well as the LPI of Sweden at the end of January 2018 (130.00) and September 2018 (131.70) [65], the adjustment amounts 35.76 €/MT.

Accordingly, the LBG MEC price (i.e. new and additional revenue per MT for the port) that would be offered by Karlskrona port to Stena Line amounts 529.24 €/MT based on the LBG baseline price, the asset costs and the adjustment. Comparing this LBG MEC price with the ULSFO price at the last trading day in September 2018 (i.e. 28 September 2018) that amounts 670.50 \$/MT or 577.72 €/MT (by using the dollar exchange rate at the same trading date with 1.1606 [62]) according to the Rotterdam Bunker Prices [66], yield cost savings for Stena Line of about 48.48 €/MT. Moreover, considering the average annual LBG consumption per ship results in average annual cost savings per ship of about € 911 484.60 for Stena Line. Deeply rooted in the fact that Stena Line operates on the route to Gdynia (Poland) with three ships, the average annual cost savings for the three vessels would amount € 2 734 453.80. Vice versa, the adjustment of 35.76 €/MT represents the potential gross profit of Karlskrona port that would be generated by the new LBG MEC business model. Hence, by taking into account the average annual LBG consumption per ship, the average annual gross profit from the new business model for Karlskrona port would be € 672 332.70 per ship, whereby the average annual gross profit in case of LBG supply to all three vessels from Stena Line would yield € 2 016 998.10. The results per MT are summarised in Fig. 1.

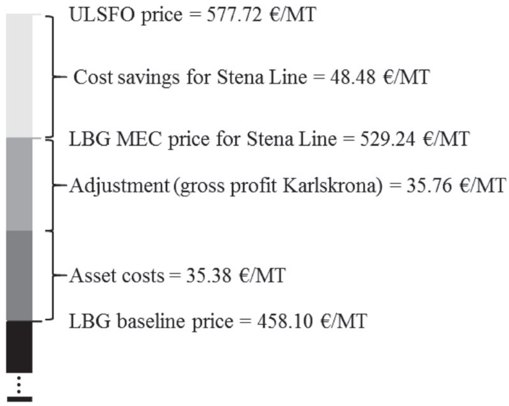

Fig. 1. Gross profits and cost savings by the LBG MEC business model.

5. Discussion and Conclusion

In this study, the possibility to supply LBG as a biofuel or renewable energy source in the maritime sector and beyond was investigated. The research revealed that the developed and proposed LBG MEC business model contributes to break through the biofuel supply and demand dilemma. However, the major challenge for LBG as a sustainable alternative biofuel for ships is the availability and supply at a competitive market price in the quantities needed for shipping [35]. As showcased in the frame of the case study, the estimated LBG baseline price can be higher, whereby due to high volatility of oil and gas prices on the market, the supply price of fossil, but emission compliance fuels like LSMFO, ULSFO, etc. can be lower, too, which may swoop the advantages of LBG utilisation. In contrast to this, a wide usage of LBG in the maritime sector is also hindered by a relatively low LNG price on the market, which can be seen as a substitute, since LNG and LBG are nearly identical, and thus, both can be replaced by each other. The use of LNG in the shipping sector is relatively widespread, wherefore the LNG bunker market is established around the globe and is expected to grow further. However, if LBG should become an alternative to LNG, LBG needs to be supplied at a competitive supply price that is approximately the same as for LNG. Otherwise, there are no economic reasons or incentives that would advocate the usage of LBG instead of LNG. Obviously, one of the most likely and realistic solutions would be subsidies that are borne by society. According to the study from Olaniyi and Gerlitz [25], the LNG baseline price was 438.60 €/MT. Hence, if LBG should compete with LNG in the long-term, subsidies must effect that the LBG baseline price level drops at least with 4 to 5 %. In this case, the derived and presented cost savings for the ship-owner in this study could be exceeded and form sufficient economic incentives for the desired entrepreneurial collaboration in the frame of the LBG MEC business model.

Another point of discussion can be seen in the fact that LBG faces the same problem as LNG, since in both fuels the main energy carrier is methane. The potential methane slip, which can occur in case of an incomplete combustion in engines as well as leakages in the biogas production [30], is a problematic aspect, since methane has a global warming potential which is 28 times higher than that for CO_2 over a 100-year perspective, and 84 times higher over 20 years [67]. Hence, innovative technology improvements and developments are needed for an efficient control and methane slip abatement, in order to fully exploit the potential of LBG as a renewable fuel for ships [68].

Furthermore, the research showed that blockchain and smart contracts are able to foster the implementation of the business model and optimisation of value chain operations. This is, because all actions and transactions can be optimally controlled between all involved actors through automated information exchange. The upstream LBG value chain nodes and entities can receive real-time information and predictive data about the current as well as expected future consumption or demand of the downstream LBG value chain – including end users. Hence, with a blockchain smart contracting system value chain management becomes smarter and thus, more efficient, since resource-optimised production along the whole chain is ensured through automatically generated real-time and forecast data. Thus, over and under capacities as well as bottlenecks can be avoided. Moreover, all occurring financial calculations, billings and transactions along the LBG value chain can be automatically elaborated and triggered by an implemented blockchain smart contracting system. Therefore, it can be concluded that blockchain and smart contracts are able to contribute substantial in the pursuit of perfection of material, information and financial flows in supply and value chains.

Next to the central entrepreneurial collaboration between port and ship-owner, the study investigated as well the possibility of a potential integration of the port in the upstream LBG value chain. As shown by the study, in case of a developed and enlarged group of customers in a maturity stage, a stronger focus on the upstream LBG value chain can make sense. The major advantages of a horizontal integration of the port into the upstream LBG value chain can be seen in higher control, short transportations, more reliable value chain, exclusion of intermediaries, and thus, decreasing transaction and enforcement costs, whereby LBG or biogas can be supplied at lower prices to the end-users. In contrast to this, the investment costs are acceptable for the development of a local or regional LBG value chain. Moreover, considering the potential gross profit that may arise from the LBG MEC business model, this supplementary step is reasonable and economically feasible. Especially for the case study seaport Karlskrona, from a spatial planning perspective, a bunker solution for LBG would make sense, since in the southern part of Sweden currently there exist no LNG or LBG bunker solution (cf. [69]). In Sweden, starting from Karlskrona, the nearest LNG bunker facilities are established or planned in Stockholm and Gothenburg, which both are far away. Hence, an LBG bunker option in Karlskrona could be an attractive alternative option due to the promising site factor that may generated a competitive advantage for the port. However, under the premise that LBG could be supplied at a competitive market price (i.e. in comparison to LNG) and in sufficient quantities, the LBG MEC business model can be easily adopted by other ports.

Next to the limitations that arise from the made assumptions (e.g. LBG is used to 100 % after retrofit and the quantity of LBG consumption is equal to the previous consumption of ULSFO), the central limitations of the study are related to the lack of available data and lack of prior research studies on the topic (i.e. especially methodological limitations). Since so far the LBG market is not established, no exact market data could be identified. Thereby, it needs to be noted that the comparative study considered no transportation and/or storage costs for ULSFO and LBG. Irrespective of what bunker solution (STS, TTS, PTS, portable tanks) is used, generally bunkering of LBG and LNG is much more complex than in case of common fuels like ULSFO, since these methane fuels stay liquid only at a temperature of -162 °C, which causes proportional higher handling, transport and especially storage costs than in case of common fuels. Hence, the presented LBG baseline price was derived from secondary data and represents an approximation only. Related to this is the lack of prior research studies on the topic, since LBG as a fuel for ships has not been widely examined in the research landscape. Hence, just a few studies record approaches on the usage of LBG in the maritime sector. Accordingly, future research activities should have a closer look on LBG or other biofuels that contribute to green shipping, in order to benchmark suitable renewable fuels and to derive environmentally friendly and feasible future development perspectives for the maritime transport sector.

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Appendix 2

1. Metric overview established Blue Economy sectors – adjacent EU states of SBSR

Employment				
Sector	Data availability	2009	2018	CAGR
Aquaculture	DK, DE, LT, PL, SE	1,908	9,840	19.993%
Coastal Tourism	DK, DE, LT, PL, SE	340,898	424,499	2.467%
Fishery	DK, DE, LT, PL, SE	8,448	7,275	-1.647%
Seabed Mining	DK, DE, (PL)	290	388	3.288%
Offshore Oil & Gas	DK, DE, PL	3,018	2,171	-3.594%
Marine Renewable Energy (Offshore Wind Energy)	DK	246	300	2.230%
Shipbuilding & Repair	DK, DE, LT, PL, SE	85,580	78,840	-0.907%
Maritime Transport	DK, DE, LT, PL, SE	278,374	351,598	2.629%
Maritime Transport attributable to ports	*DK, DE, LT, PL, SE*	*113,675*	*168,685*	*4.483%*
Total		718,762	874,911	
Turnover (in million EUR)				
Sector	Data availability	2009	2018	CAGR
Aquaculture	DK, DE, LT, PL, SE	354.4	455.4	2.825%
Coastal Tourism	DK, DE, LT, PL, SE	25,234.8	36,297.2	4.122%
Fishery	DK, DE, LT, PL, SE	676.5	801.0	1.895%
Seabed Mining	DK, DE, (PL)	59.0	93.0	5.186%
Offshore Oil & Gas	DK, DE, LT, PL	6,465.6	3,434.3	-6.788%
Marine Renewable Energy (Offshore Wind Energy)	DK	168.1	1,147.5	23.790%
Shipbuilding & Repair	DK, DE, LT, PL, SE	13,525.5	17,499.0	2.903%
Maritime Transport	DK, DE, LT, PL, SE	82,916.6	118,854.3	4.082%
Maritime Transport attributable to ports	*DK, DE, LT, PL, SE*	*12,343.1*	*23,246.0*	*7.287%*
Total		129,400.5	178,581.7	
GVA (in million EUR)				
Sector	Data availability	2009	2018	CAGR
Aquaculture	DK, DE, LT, PL, SE	142.5	204.4	4.090%
Coastal Tourism	DK, DE, LT, PL, SE	8,886.6	12,763.5	4.105%
Fishery	DK, DE, LT, PL, SE	360.5	419.5	1.698%
Seabed Mining	DK, DE, (PL)	23.9	34.5	4.163%
Offshore Oil & Gas	DK, DE, LT, PL	5,139.9	1,496.7	-12.810%
Marine Renewable Energy (Offshore Wind Energy)	DK	37.7	463.4	32.150%
Shipbuilding & Repair	DK, DE, LT, PL, SE	3,587.0	4,617.9	2.847%
Maritime Transport	DK, DE, LT, PL, SE	21,665.2	26,442.3	2.239%
Maritime Transport attributable to ports	*DK, DE, LT, PL, SE*	*5,246.9*	*8,752.2*	*5.850%*
Total		39,843.3	46,442.2	

Source: Compiled by author, based on: EC, 2020.

2. Employment established Blue Economy sectors – adjacent EU states of SBSR

		Employment																	
		Denmark			Germany			Lithuania			Poland			Sweden			**Total**		
Sector	Subsector	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	**2009**	**2018**	**CAGR**
Aquaculture	Marine aquaculture	90	150	5.840%													*90*	*150*	*5.840%*
	Freshwater aquaculture	375	389	0.408%	815	823	0.109%	63	140	9.278%	58	7,764	72.304%	339	369	0.947%	*1,650*	*9,485*	*21.449%*
	Shellfish aquaculture	25	10	-9.680%	58	127	9.099%							85	68	-2.449%	*168*	*205*	*2.236%*
	Total	**490**	**549**	**1.271%**	**873**	**950**	**0.944%**	**63**	**140**	**9.278%**	**58**	**7,764**	**72.304%**	**424**	**437**	**0.336%**	***1,908***	***9,840***	***19.993%***
Coastal Tourism	Accommodation	20,154	28,334	3.858%	98,391	97,605	-0.089%	2,246	2,701	2.071%	11,741	23,314	7.920%	32,739	31,626	-0.384%	*165,271*	*183,580*	*1.174%*
	Transport	8,158	12,454	4.813%	33,842	33,847	0.002%	1,409	837	-5.623%	6,619	12,879	7.677%	16,384	15,525	-0.597%	*66,412*	*75,542*	*1.442%*
	Other expenditure	15,706	36,766	9.911%	48,248	69,540	4.145%	2,509	2,373	-0.617%	9,623	22,658	9.982%	33,129	34,040	0.302%	*109,215*	*165,377*	*4.718%*
	Total	**44,018**	**77,554**	**6.495%**	**180,481**	**200,992**	**1.203%**	**6,164**	**5,911**	**-0.465%**	**27,983**	**58,851**	**8.611%**	**82,252**	**81,191**	**-0.144%**	***340,898***	***424,499***	***2.467%***
Fishery	Capture Fisheries (SSCF)	378	278	-3.357%	559	807	4.164%	160	145	-1.088%	1,313	1,442	1.047%	995	809	-2.273%	*3,405*	*3,481*	*0.246%*
	Capture Fisheries (LSF)	1,317	999	-3.024%	970	849	-1.470%	192	122	-4.914%	1,116	886	-2.532%	868	602	-3.984%	*4,463*	*3,458*	*-2.795%*
	Capture Fisheries (DWF)							310	196	-4.966%	270	140	-7.038%				*580*	*336*	*-5.885%*
	Total	**1,695**	**1,277**	**-3.097%**	**1,529**	**1,656**	**0.891%**	**662**	**463**	**-3.895%**	**2,699**	**2,468**	**-0.989%**	**1,863**	**1,411**	**-3.040%**	***8,448***	***7,275***	***-1.647%***
Seabed Mining	Operation of gravel and sand pits; mining of clays and kaolin	149	84	-6.170%	140	301	8.877%					(17)					*289*	*385*	*3.238%*
	Support activities for mining and quarrying	1	3	12.983%								(2)					*1*	*3*	*12.983%*
	Total	**150**	**87**	**-5.873%**	**140**	**301**	**8.877%**					**(19)**					***290***	***388***	***3.288%***
Offshore Oil & Gas	Extraction of crude petroleum	514	672	3.023%							62	35	-6.156%				*576*	*707*	*2.303%*
	Extraction of natural gas				145	35	-14.609%					(1)					*145*	*35*	*-14.609%*
	Support activities for petroleum and natural gas extraction	1,935	1,274	-4.538%							362	155	-8.994%				*2,297*	*1,429*	*-5.137%*
	Total	**2,449**	**1,946**	**-2.522%**	**145**	**35**	**-14.609%**				**424**	**190**	**-8.533%**				***3,018***	***2,171***	***-3.594%***
Marine Renewable Energy (Offshore Wind Energy)	Production of electricity	216	113	-6.946%													*216*	*113*	*-6.946%*
	Transmission of electricity	30	187	22.547%													*30*	*187*	*22.547%*
	Total	**246**	**300**	**2.230%**													***246***	***300***	***2.230%***
Shipbuilding & Repair	Building of ships and floating structures	2,300	912	-9.767%	15,288	13,067	-1.729%	1,708	1,300	-2.987%	14,268	4,925	-11.147%	1,646	1,563	-0.573%	*35,210*	*21,767*	*-5.203%*
	Building of pleasure and sporting boats	225	257	1.488%	3,747	6,171	5.700%	166	312	7.263%	3,957	6,567	5.790%	2,135	1,302	-5.347%	*10,230*	*14,609*	*4.038%*
	Repair and maintenance of ships and boats	1,333	1,792	3.342%	6,871	6,777	-0.153%	3,464	2,741	-2.568%	9,717	10,483	0.847%	1,871	2,107	1.329%	*23,256*	*23,900*	*0.304%*
	Manufacture of engines and turbines	402	30	-25.051%	9,571	8,996	-0.686%	(27)			(885)			724	647	-1.242%	*10,697*	*9,673*	*-1.112%*
	Manufacture of instruments for measuring, testing and navigation	23	63	11.847%	1,433	1,405	-0.219%	24	68	12.268%	37	98	11.430%	103	119	1.617%	*1,620*	*1,753*	*0.881%*
	Manufacture of other fabricated metal products n.e.c.	114	12	-22.131%	2,607	389	-19.053%	(1)			101	1	-40.118%	483	682	3.908%	*3,305*	*1,084*	*-11.650%*
	Manufacture of sport goods				84	35	-9.269%	14	15	0.770%	321	192	-5.551%	45	27	-5.518%	*464*	*269*	*-5.878%*
	Manufacture of cordage, rope, twine and netting	56	95	6.048%				423	387	-0.983%	(45)				(28)		*479*	*482*	*0.069%*
	Manufacture of textiles other than apparel	88	103	1.764%	4	2,824	107.269%	152	105	-4.027%	43	1,521	48.619%	32	750	41.975%	*319*	*5,303*	*36.659%*
	Total	**4,541**	**3,264**	**-3.602%**	**39,605**	**39,664**	**0.017%**	**5,951**	**4,928**	**-2.074%**	**28,444**	**23,787**	**-1.967%**	**7,039**	**7,197**	**0.247%**	***85,580***	***78,840***	***-0.907%***
Maritime Transport (incl. Port Activities)	Sea and coastal passenger water transport	4,420	5,351	2.147%	1,604	3,629	9.496%				374	538	4.123%	9,671	8,479	-1.451%	*16,069*	*17,997*	*1.267%*
	Inland passenger water transport	155	132	-1.769%	4,446	6,103	3.582%	143	130	-1.053%	699	479	-4.112%	983	1,584	5.444%	*6,426*	*8,428*	*3.059%*
	Sea and coastal freight water transport	14,285	12,350	-1.604%	26,803	14,728	-6.436%	1,602	1,018	-4.913%	1,858	1,427	-2.890%	6,719	3,451	-7.136%	*51,267*	*32,974*	*-4.785%*
	Inland freight water transport	28	25	-1.251%	4,082	4,211	0.346%				723	734	0.168%	161	112	-3.952%	*4,994*	*5,082*	*0.194%*
	Renting and leasing of water transport equipment	47	69	4.359%	2,070	2,359	1.463%	32	117	15.494%	125	283	9.504%	60	117	7.703%	*2,334*	*2,945*	*2.617%*
	Other transport support activities	8,212	9,769	1.948%	70,364	101,551	4.161%	334	313	-0.719%	685	437	-4.872%	4,014	3,417	-1.773%	*83,609*	*115,487*	*3.654%*
	Cargo handling by ports	145	187	2.867%	2,031	3,470	6.132%	1,015	1,026	0.120%	7,804	5,677	-3.474%	834	829	-0.067%	*11,829*	*11,189*	*-0.616%*
	Warehousing and storage by ports	1,284	1,985	4.959%	51,626	100,711	7.707%	1,068	1,797	5.952%	8,258	17,702	8.841%	218	318	4.284%	*62,454*	*122,513*	*7.774%*
	Construction of water projects by ports	634	711	1.282%	2,648	2,950	1.207%	1,116	638	-6.024%	9,511	6,106	-4.805%	521	452	-1.566%	*14,430*	*10,857*	*-3.112%*
	Service activities incidental to water transportation by ports	1,376	2,849	8.422%	18,074	16,674	-0.892%	654	535	-2.207%	2,418	1,805	-3.196%	2,440	2,263	-0.833%	*24,962*	*24,126*	*-0.378%*
	Total (Port)	**3,439**	**5,732**	**5.841%**	**74,379**	**123,805**	**5.825%**	**3,853**	**3,996**	**0.406%**	**27,991**	**31,290**	**1.246%**	**4,013**	**3,862**	**-0.425%**	***113,675***	***168,685***	***4.483%***
	Total	**30,586**	**33,428**	**0.992%**	**183,748**	**256,386**	**3.771%**	**5,964**	**5,574**	**-0.749%**	**32,455**	**35,188**	**0.902%**	**25,621**	**21,022**	**-2.174%**	***278,374***	***351,598***	***2.629%***
Total		**84,175**	**118,405**		**406,521**	**499,984**		**18,804**	**17,016**		**92,063**	**128,248**		**117,199**	**111,258**		***718,762***	***874,911***	

Source: Compiled by author, based on: EC, 2020.

Note: Numbers in brackets were not taken into account in the frame of sums and CARG calculations due to missing annual comparative figures. Moreover, the secondary sector Processing and Distribution of Fish Products was excluded, since the focus within the doctoral thesis is on the upstream primary sectors Aquaculture and Fishery.

3. Turnover established Blue Economy sectors – adjacent EU states of SBSR

		Turnover (in million EUR)																	
		Denmark			Germany			Lithuania			Poland			Sweden			**Total**		
Sector	Subsector	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	**2009**	**2018**	**CAGR**
Aquaculture	Marine aquaculture	42.7	63.3	4.471%													*42.7*	*63.3*	*4.471%*
	Freshwater aquaculture	95.7	124.8	2.994%	93.5	78.7	-1.896%	7.2	13.4	7.146%	76.7	89.4	1.717%	29.8	57.1	7.493%	*302.9*	*363.4*	*2.044%*
	Shellfish aquaculture	1.8	1.4	-2.754%	5.8	25.3	17.781%							1.2	2.0	5.840%	*8.8*	*28.7*	*14.037%*
	Total	**140.2**	**189.5**	**3.405%**	**99.3**	**104.0**	**0.515%**	**7.2**	**13.4**	**7.146%**	**76.7**	**89.4**	**1.717%**	**31.0**	**59.1**	**7.433%**	***354.4***	***455.4***	***2.825%***
Coastal Tourism	Accommodation	1,777.0	2,893.6	5.567%	4,058.2	5,139.8	2.660%	41.4	77.6	7.230%	297.9	999.1	14.391%	2,450.2	2,894.0	1.867%	*8,624.7*	*12,004.1*	*3.742%*
	Transport	1,455.4	2,520.2	6.291%	3,750.7	3,981.5	0.666%	100.9	82.7	-2.186%	362.1	1,090.8	13.035%	2,473.5	2,860.8	1.629%	*8,142.6*	*10,536.0*	*2.905%*
	Other expenditure	1,571.6	3,323.7	8.678%	3,130.2	5,061.4	5.485%	66.6	90.3	3.440%	424.7	1,394.0	14.118%	3,274.4	3,887.7	1.926%	*8,467.5*	*13,757.1*	*5.540%*
	Total	**4,804.0**	**8,737.5**	**6.872%**	**10,939.1**	**14,182.7**	**2.927%**	**208.9**	**250.6**	**2.043%**	**1,084.7**	**3,483.9**	**13.843%**	**8,198.1**	**9,642.5**	**1.819%**	***25,234.8***	***36,297.2***	***4.122%***
Fishery	Capture Fisheries (SSCF)	25.1	23.1	-0.918%	9.0	7.7	-1.718%	0.9	0.7	-2.754%	10.8	10.4	-0.418%	16.3	13.3	-2.235%	*62.1*	*55.2*	*-1.300%*
	Capture Fisheries (LSF)	292.7	375.6	2.810%	127.4	168.8	3.176%	7.6	5.6	-3.336%	30.9	38.3	2.414%	103.0	105.3	0.246%	*561.6*	*693.6*	*2.373%*
	Capture Fisheries (DWF)							52.8	52.2	-0.127%							*52.8*	*52.2*	*-0.127%*
	Total	**317.8**	**398.7**	**2.552%**	**136.4**	**176.5**	**2.905%**	**61.3**	**58.5**	**-0.518%**	**41.7**	**48.7**	**1.739%**	**119.3**	**118.6**	**-0.065%**	***676.5***	***801.0***	***1.895%***
Seabed Mining	Operation of gravel and sand pits; mining of clays and kaolin	37.8	34.5	-1.010%	20.8	57.8	12.026%					(1.3)					*58.6*	*92.3*	*5.177%*
	Support activities for mining and quarrying	0.4	0.7	6.415%								(0.1)					*0.4*	*0.7*	*6.415%*
	Total	**38.2**	**35.2**	**-0.905%**	**20.8**	**57.8**	**12.026%**					**(1.4)**					***59.0***	***93.0***	***5.186%***
Offshore Oil & Gas	Extraction of crude petroleum	5,910.2	2,896.5	-7.618%				0.0	0.0		15.7	8.9	-6.112%				*5,925.9*	*2,905.4*	*-7.614%*
	Extraction of natural gas				106.3	26.8	-14.195%				0.0	0.2					*106.3*	*27.0*	*-14.124%*
	Support activities for petroleum and natural gas extraction	405.4	490.5	2.140%							28.0	11.4	-9.502%				*433.4*	*501.9*	*1.644%*
	Total	**6,315.6**	**3,387.0**	**-6.689%**	**106.3**	**26.8**	**-14.195%**	**0.0**	**0.0**		**43.7**	**20.5**	**-8.066%**				***6,465.6***	***3,434.3***	***-6.788%***
Marine Renewable Energy (Offshore Wind Energy)	Production of electricity	132.6	1,029.7	25.576%													*132.6*	*1,029.7*	*25.576%*
	Transmission of electricity	35.5	117.8	14.256%													*35.5*	*117.8*	*14.256%*
	Total	**168.1**	**1,147.5**	**23.790%**													***168.1***	***1,147.5***	***23.790%***
Shipbuilding & Repair	Building of ships and floating structures	617.1	393.1	-4.887%	3,880.3	5,175.5	3.252%	54.7	68.6	2.548%	1,225.4	631.4	-7.103%	220.7	369.2	5.884%	*5,998.2*	*6,637.8*	*1.132%*
	Building of pleasure and sporting boats	59.2	53.2	-1.180%	983.0	2,239.0	9.578%	5.8	22.0	15.967%	163.7	451.2	11.924%	261.9	216.1	-2.113%	*1,473.6*	*2,981.5*	*8.145%*
	Repair and maintenance of ships and boats	299.6	424.8	3.956%	1,252.0	1,038.6	-2.055%	195.6	137.4	-3.848%	396.1	794.7	8.044%	288.7	339.6	1.821%	*2,432.0*	*2,735.1*	*1.314%*
	Manufacture of engines and turbines	248.4	22.2	-23.534%	2,357.6	3,633.2	4.923%	(0.5)			(120.5)			207.9	271.0	2.989%	*2,813.9*	*3,926.4*	*3.771%*
	Manufacture of instruments for measuring, testing and navigation	4.1	17.1	17.196%	218.6	296.1	3.429%	1.1	6.3	21.399%	1.7	8.7	19.891%	19.1	29.2	4.829%	*244.6*	*357.4*	*4.304%*
	Manufacture of other fabricated metal products n.e.c.	18.1	1.9	-22.155%	398.5	62.9	-18.546%	(0.0)			4.5	0.0		63.5	118.7	7.198%	*484.6*	*183.5*	*-10.228%*
	Manufacture of sport goods				10.5	4.9	-8.120%	0.5	0.8	5.361%	9.3	9.5	0.237%	7.1	5.0	-3.821%	*27.4*	*20.2*	*-3.331%*
	Manufacture of cordage, rope, twine and netting	10.1	20.9	8.416%				17.9	20.2	1.352%	(2.1)			0.1	5.1	54.785%	*28.1*	*46.2*	*5.680%*
	Manufacture of textiles other than apparel	14.0	21.6	4.936%	0.5	394.9	109.868%	4.1	4.9	2.000%	1.5	80.8	55.729%	3.0	108.7	49.016%	*23.1*	*610.9*	*43.893%*
	Total	**1,270.6**	**954.8**	**-3.125%**	**9,101.0**	**12,845.1**	**3.903%**	**279.7**	**260.2**	**-0.800%**	**1,802.2**	**1,976.3**	**1.030%**	**1,072.0**	**1,462.6**	**3.512%**	***13,525.5***	***17,499.0***	***2.903%***
Maritime Transport (incl. Port Activities)	Sea and coastal passenger water transport	1,174.1	2,178.9	7.112%	369.6	3,142.9	26.849%				42.2	86.3	8.273%	1,186.3	1,805.1	4.775%	*2,772.2*	*7,213.2*	*11.210%*
	Inland passenger water transport	81.9	20.4	-14.311%	412.6	545.2	3.145%	4.4	5.0	1.431%	84.6	13.0	-18.788%	79.5	186.7	9.951%	*663.0*	*770.3*	*1.681%*
	Sea and coastal freight water transport	22,904.9	26,150.7	1.483%	20,963.1	29,909.1	4.028%	147.2	137.6	-0.747%	288.6	322.9	1.256%	2,331.9	1,599.3	-4.104%	*46,635.7*	*58,119.6*	*2.476%*
	Inland freight water transport	5.5	6.9	2.552%	1,647.9	1,689.1	0.275%				105.7	77.6	-3.375%	12.0	16.4	3.532%	*1,771.1*	*1,790.0*	*0.118%*
	Renting and leasing of water transport equipment	47.2	88.5	7.234%	1,449.4	523.6	-10.697%	2.2	83.0	49.687%	20.4	9.1	-8.579%	81.1	58.1	-3.638%	*1,600.3*	*762.3*	*-7.910%*
	Other transport support activities	3,435.1	5,218.2	4.755%	12,125.8	19,965.7	5.697%	53.5	74.3	3.717%	71.5	79.6	1.200%	1,445.3	1,615.1	1.242%	*17,131.2*	*26,952.9*	*5.164%*
	Cargo handling by ports	19.2	30.2	5.161%	284.2	591.4	8.483%	59.6	121.6	8.245%	418.3	419.1	0.021%	81.5	122.2	4.603%	*862.8*	*1,284.5*	*4.521%*
	Warehousing and storage by ports	305.9	481.0	5.158%	5,626.5	13,179.0	9.919%	46.9	115.0	10.479%	385.1	1,974.1	19.913%	33.3	52.0	5.077%	*6,397.7*	*15,801.1*	*10.568%*
	Construction of water projects by ports	310.0	356.2	1.556%	302.9	629.7	8.471%	45.5	43.1	-0.600%	893.5	391.0	-8.774%	82.2	83.9	0.228%	*1,634.1*	*1,503.9*	*-0.918%*
	Service activities incidental to water transportation by ports	287.9	565.3	7.785%	2,581.9	3,396.7	3.094%	55.7	84.4	4.726%	209.2	211.4	0.116%	313.8	398.7	2.696%	*3,448.5*	*4,656.5*	*3.393%*
	Total (Port)	**923.0**	**1,432.7**	**5.007%**	**8,795.5**	**17,796.8**	**8.146%**	**207.7**	**364.1**	**6.436%**	**1,906.1**	**2,995.6**	**5.151%**	**510.8**	**656.8**	**2.833%**	***12,343.1***	***23,246.0***	***7.287%***
	Total	**28,571.7**	**35,096.3**	**2.312%**	**45,763.9**	**73,572.4**	**5.417%**	**415.0**	**664.0**	**5.361%**	**2,519.1**	**3,584.1**	**3.996%**	**5,646.9**	**5,937.5**	**0.559%**	***82,916.6***	***118,854.3***	***4.082%***
Total		**41,626.2**	**49,946.5**		**66,166.8**	**100,965.3**		**972.1**	**1,246.7**		**5,568.1**	**9,201.5**		**15,067.3**	**17,220.3**		***129,400.5***	***178,581.7***	

Source: Compiled by author, based on: EC, 2020.

Note: Numbers in brackets were not taken into account in the frame of sums and CARG calculations due to missing annual comparative figures. Moreover, the secondary sector Processing and Distribution of Fish Products was excluded, since the focus within the doctoral thesis is on the upstream primary sectors Aquaculture and Fishery.

4. GVA established Blue Economy sectors – adjacent EU states of SBSR

		GVA (in million EUR)																	
		Denmark			Germany			Lithuania			Poland			Sweden			Total		
Sector	Subsector	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR	2009	2018	CAGR
Aquaculture	Marine aquaculture	3.8	14.6	16.132%													3.8	14.6	16.132%
	Freshwater aquaculture	23.7	29.6	2.501%	26.2	23.9	-1.016%	2.0	4.1	8.303%	74.7	86.8	1.682%	8.2	28.3	14.756%	134.8	172.7	2.791%
	Shellfish aquaculture	0.6	0.8	3.248%	2.7	14.4	20.442%							0.6	1.9	13.664%	3.9	17.1	17.849%
	Total	**28.1**	**45.0**	**5.371%**	**28.9**	**38.3**	**3.178%**	**2.0**	**4.1**	**8.303%**	**74.7**	**86.8**	**1.682%**	**8.8**	**30.2**	**14.684%**	**142.5**	**204.4**	**4.090%**
Coastal Tourism	Accommodation	752.5	1,186.0	5.185%	2,164.1	2,603.5	2.075%	17.5	41.0	9.922%	130.5	437.6	14.389%	1,014.6	1,255.4	2.394%	4,079.2	5,523.5	3.425%
	Transport	464.0	858.5	7.076%	1,215.7	1,296.9	0.721%	12.1	14.0	1.634%	85.1	250.2	12.730%	611.0	829.4	3.454%	2,387.9	3,249.0	3.481%
	Other expenditure	460.4	1,018.9	9.228%	949.6	1,478.6	5.043%	11.4	22.5	7.847%	81.0	276.2	14.602%	917.1	1,194.8	2.983%	2,419.5	3,991.0	5.718%
	Total	**1,676.9**	**3,063.4**	**6.925%**	**4,329.4**	**5,379.0**	**2.441%**	**41.0**	**77.5**	**7.331%**	**296.6**	**964.0**	**13.993%**	**2,542.7**	**3,279.6**	**2.868%**	**8,886.6**	**12,763.5**	**4.105%**
Fishery	Capture Fisheries (SSCF)	12.3	11.4	-0.841%	2.5	2.1	-1.919%	0.5	0.3	-5.518%	7.6	6.1	-2.413%	8.7	6.6	-3.023%	31.6	26.5	-1.937%
	Capture Fisheries (LSF)	175.1	240.8	3.604%	62.6	80.8	2.876%	2.5	1.8	-3.584%	16.2	18.5	1.486%	60.7	47.6	-2.665%	317.1	389.5	2.311%
	Capture Fisheries (DWF)							11.8	3.5	-12.632%							11.8	3.5	-12.632%
	Total	**187.4**	**252.2**	**3.355%**	**65.1**	**82.9**	**2.722%**	**14.8**	**5.6**	**-10.236%**	**23.8**	**24.6**	**0.368%**	**69.4**	**54.2**	**-2.709%**	**360.5**	**419.5**	**1.698%**
Seabed Mining	Operation of gravel and sand pits; mining of clays and kaolin	15.2	12.3	-2.325%	8.6	22.0	11.000%					(0.5)					23.8	34.3	4.144%
	Support activities for mining and quarrying	0.1	0.2	8.006%								(0.1)					0.1	0.2	8.006%
	Total	**15.3**	**12.5**	**-2.221%**	**8.6**	**22.0**	**11.000%**					**(0.6)**					**23.9**	**34.5**	**4.163%**
Offshore Oil & Gas	Extraction of crude petroleum	4,818.2	1,310.0	-13.473%				0.0	0.0		4.3	2.5	-5.848%				4,822.5	1,312.5	-13.463%
	Extraction of natural gas				45.0	6.4	-19.483%					(0.0)					45.0	6.4	-19.483%
	Support activities for petroleum and natural gas extraction	258.2	172.2	-4.401%							14.2	5.6	-9.822%				272.4	177.8	-4.630%
	Total	**5,076.4**	**1,482.2**	**-12.784%**	**45.0**	**6.4**	**-19.483%**	**0.0**	**0.0**		**18.5**	**8.1**	**-8.768%**				**5,139.9**	**1,496.7**	**-12.810%**
Marine Renewable Energy (Offshore Wind Energy)	Production of electricity	25.0	387.1	35.584%													25.0	387.1	35.584%
	Transmission of electricity	12.7	76.3	22.046%													12.7	76.3	22.046%
	Total	**37.7**	**463.4**	**32.150%**													**37.7**	**463.4**	**32.150%**
Shipbuilding & Repair	Building of ships and floating structures	123.8	94.0	-3.013%	783.1	1,080.2	3.638%	33.4	26.5	-2.538%	438.0	121.7	-13.264%	56.0	119.1	8.746%	1,434.3	1,441.5	0.056%
	Building of pleasure and sporting boats	16.1	14.5	-1.156%	256.8	528.8	8.357%	1.1	8.8	25.992%	56.6	132.6	9.921%	69.5	58.9	-1.822%	400.1	743.6	7.129%
	Repair and maintenance of ships and boats	92.1	159.9	6.321%	423.6	354.2	-1.968%	35.5	60.0	6.005%	179.2	313.4	6.408%	82.7	112.2	3.448%	813.1	999.7	2.322%
	Manufacture of engines and turbines	45.2	3.6	-24.507%	569.0	907.0	5.317%	(0.3)			(32.5)			47.3	78.0	5.715%	661.5	988.6	4.565%
	Manufacture of instruments for measuring, testing and navigation	1.9	8.2	17.642%	82.4	123.1	4.561%	0.5	2.7	20.608%	0.7	2.6	15.696%	7.3	12.7	6.346%	92.8	149.3	5.426%
	Manufacture of other fabricated metal products n.e.c.	6.9	0.8	-21.291%	131.1	23.9	-17.231%	(0.0)			1.5	0.0		20.7	41.5	8.035%	160.2	66.2	-9.353%
	Manufacture of sport goods				3.5	1.7	-7.710%	0.1	0.2	8.006%	3.8	2.6	-4.129%	2.2	1.4	-4.898%	9.6	5.9	-5.265%
	Manufacture of cordage, rope, twine and netting	2.6	8.1	13.458%				5.3	8.0	4.681%	(0.7)			0.0	1.6		7.9	17.7	9.377%
	Manufacture of textiles other than apparel	4.6	6.9	4.608%	0.1	139.9	123.633%	1.2	1.4	1.728%	0.5	19.8	50.495%	1.1	37.4	47.967%	7.5	205.4	44.453%
	Total	**293.2**	**296.0**	**0.106%**	**2,249.6**	**3,158.8**	**3.844%**	**77.1**	**107.6**	**3.773%**	**680.3**	**592.7**	**-1.520%**	**286.8**	**462.8**	**5.461%**	**3,587.0**	**4,617.9**	**2.847%**
Maritime Transport (incl. Port Activities)	Sea and coastal passenger water transport	413.6	758.8	6.975%	218.4	1,533.0	24.174%				14.4	12.7	-1.386%	315.6	382.1	2.147%	962.0	2,686.6	12.088%
	Inland passenger water transport	3.3	11.4	14.768%	185.7	304.4	5.645%	3.4	3.3	-0.331%	27.0	6.9	-14.066%	16.4	80.8	19.386%	235.8	406.8	6.247%
	Sea and coastal freight water transport	1,776.4	2,906.6	5.623%	6,924.4	4,167.8	-5.485%	52.7	55.4	0.557%	87.8	119.7	3.504%	216.0	291.4	3.383%	9,057.3	7,540.9	-2.015%
	Inland freight water transport	2.7	1.5	-6.322%	650.5	385.3	-5.653%				32.3	15.3	-7.967%	4.0	6.6	5.722%	689.5	408.7	-5.645%
	Renting and leasing of water transport equipment	25.5	33.0	2.906%	871.8	291.4	-11.464%	0.5	4.7	28.270%	10.4	1.9	-17.212%	70.2	47.2	-4.315%	978.4	378.2	-10.023%
	Other transport support activities	633.8	850.6	3.323%	3,638.9	5,188.4	4.020%	5.1	7.4	4.223%	14.4	11.0	-2.948%	203.1	211.5	0.451%	4,495.3	6,268.9	3.764%
	Cargo handling by ports	9.5	18.6	7.751%	125.2	265.8	8.725%	32.5	56.3	6.295%	161.2	190.5	1.873%	49.1	62.5	2.717%	377.5	593.7	5.160%
	Warehousing and storage by ports	134.2	202.8	4.695%	2,143.1	4,630.6	8.937%	20.0	33.7	5.969%	116.7	389.2	14.320%	12.2	21.9	6.717%	2,426.2	5,278.2	9.020%
	Construction of water projects by ports	52.1	84.9	5.576%	117.1	214.0	6.929%	15.7	12.1	-2.852%	206.0	102.2	-7.493%	24.0	25.0	0.455%	414.9	438.2	0.609%
	Service activities incidental to water transportation by ports	193.9	370.1	7.447%	1,555.0	1,713.8	1.086%	44.5	63.6	4.048%	79.3	71.8	-1.098%	155.6	222.8	4.069%	2,028.3	2,442.1	2.084%
	Total (Port)	**389.7**	**676.4**	**6.318%**	**3,940.4**	**6,824.2**	**6.292%**	**112.7**	**165.7**	**4.376%**	**563.2**	**753.7**	**3.290%**	**240.9**	**332.2**	**3.635%**	**5,246.9**	**8,752.2**	**5.850%**
	Total	**3,245.0**	**5,238.3**	**5.465%**	**16,430.1**	**18,694.5**	**1.445%**	**174.4**	**236.5**	**3.442%**	**749.5**	**921.2**	**2.318%**	**1,066.2**	**1,351.8**	**2.672%**	**21,665.2**	**26,442.3**	**2.239%**
Total		**10,560.0**	**10,853.0**		**23,156.7**	**27,381.9**		**309.3**	**431.3**		**1,843.4**	**2,596.8**		**3,973.9**	**5,178.6**		**39,843.3**	**46,442.2**	

Source: Compiled by author, based on: EC, 2020.

Note: Numbers in brackets were not taken into account in the frame of sums and CARG calculations due to missing annual comparative figures. Moreover, the secondary sector Processing and Distribution of Fish Products was excluded, since the focus within the doctoral thesis is on the upstream primary sectors Aquaculture and Fishery.

Appendix 3

1. Classification of small and medium-sized ports in SBSR according to the TEN-T

No.	Country	Small and medium-sized ports	Comprehensive	Non-TEN-T
1.	Denmark	Rødby	✓	
2.		Gedser	✓	
3.		Køge	✓	
4.		Rønne	✓	
5.		Kalundborg	✓	
6.		Statoil-Havnen	✓	
7.		Asnæsværkets Havn		✓
8.		Gulfhavn		✓
9.	Germany	Wismar	✓	
10.		Sassnitz	✓	
11.		Stralsund		✓
12.		Wolgast		✓
13.		Berndshof		✓
14.		Greifswald		✓
15.	Lithuania	Butinge		✓
16.	Poland	Police	✓	
17.	Sweden	Helsingborg	✓	
18.		Karlshamn	✓	
19.		Ystad	✓	
20.		Karlskrona	✓	
21.		Oskarshamn	✓	
22.		Sölvesborg		✓
23.		Kalmar		✓
24.		Mönsterås		✓
25.		Åhus		✓
26.		Landskrona		✓
27.		Västervik		✓
28.		Elleholm		✓

Source: Compiled by author, based on: Eurostat, 2018b; EC, 2013b; Saurama et al., 2008; INTERREG South Baltic, n.d.

2. Freight specialisation of small and medium-sized ports in SBSR

		Total in 2016	Shares					
Country	Ports (*comprehensive port)	Thousand tonnes	Liquid bulk goods	Dry bulk goods	Container	Ro-Ro mobile s-p units	Ro-Ro mobile non s-p units	not specified
Denmark	Rødby*	7,214	0%	0%	0%	**100%**	0%	0%
	Gedser*	2,018	0%	0%	0%	**100%**	0%	0%
	Køge*	2,079	3%	**62%**	0%	3%	19%	12%
	Rønne*	1,475	4%	**56%**	0%	7%	31%	2%
	Kalundborg*	1,004	14%	**71%**	6%	4%	0%	5%
	Statoil-Havnen*	8,060	**100%**	0%	0%	0%	0%	0%
	Asnæsværkets Havn	1,521	**71%**	29%	0%	0%	0%	0%
	Gulfhavn	968	**100%**	0%	0%	0%	0%	0%
Germany	Wismar*	3,243	3%	47%	0%	0%	0%	**49%**
	Sassnitz*	1,339	0%	**49%**	0%	4%	1%	46%
	Stralsund	865	0%	**81%**	0%	0%	0%	19%
	Wolgast	123	3%	**94%**	0%	0%	0%	2%
	Berndshof	94	0%	**60%**	0%	0%	0%	40%
	Greifswald	95	48%	**52%**	0%	0%	0%	0%
Lithuania	Butinge	9,315	**100%**	0%	0%	0%	0%	0%
Poland	Police*	1,739	3%	**97%**	0%	0%	0%	0%
Sweden	Helsingborg*	8,886	10%	10%	23%	**54%**	0%	3%
	Karlshamn*	4,299	**40%**	11%	0%	36%	0%	13%
	Ystad*	3,443	0%	3%	0%	**89%**	7%	1%
	Karlskrona*	1,765	0%	1%	0%	**92%**	6%	2%
	Oskarshamn*	723	6%	10%	0%	**37%**	10%	**37%**
	Sölvesborg	732	10%	21%	0%	0%	0%	**69%**
	Kalmar	928	**46%**	22%	0%	0%	0%	32%
	Mönsterås	818	6%	0%	0%	0%	0%	**94%**
	Åhus	617	0%	**74%**	22%	0%	0%	3%
	Landskrona	562	4%	**86%**	0%	0%	0%	10%
	Västervik	176	**54%**	11%	0%	0%	0%	34%
	Elleholm	319	0%	**100%**	0%	0%	0%	0%

Source: Compiled by author, based on: Eurostat, 2018b; EC, 2013b; Saurama et al., 2008; INTERREG South Baltic, n.d.

Appendix 4

1. Online Survey: Future Potential of Maritime Economy in South Baltic Sea Region

INTERMARE South Baltic Project Team relies on You and Your feedback!

Why do we collect and use your data

QUESTIONNAIRE ON FUTURE POTENTIAL OF MARITIME ECONOMY IN SOUTH BALTIC REGION
in the frame of the EU project "INTERMARE South Baltic – Internationalization of South Baltic maritime economy", part-financed by the European Regional Development Fund (ERDF) within the Interreg South Baltic Programme 2014–2020.

PROJECT AND QUESTIONNAIRE FICHE
INTERMARE South Baltic is a non-profit project that focus on strengthening international activeness and innovation capacity of the South Baltic blue & green economy. The project targets to increase the presence of blue and green sector SMEs from the South Baltic area in international markets through joint cross-border actions. It supports the maritime economy in South Baltic Sea Region by a network of companies and stakeholders under a common brand INTERMARE South Baltic, easily recognised in the region and in other European and global markets.
The aim of the Questionnaire "Future Potential of Maritime Economy in South Baltic Region" is to identify and analyse the future potential of – as well as trends that currently or in the near future affect – SMEs of the Blue Economy in the Southern Baltic Sea Region.
It takes you only 5 minutes to complete this questionnaire.

DATA PROTECTION CLAUSE AND DECLARATION OF CONSENT
This declaration of consent asks you to allow the researcher to record and use your answers and information to enhance knowledge and understanding of the declared topic and research field mentioned above. Participation in this questionnaire is completely voluntary.
The researcher will always maintain the confidentiality of the research records and data. Furthermore, the researcher will not disclose any sensitive organisational or personal data provided by you to any third party. Data collected will be analysed in an aggregated form anonymously and for research and scientific purposes only. All collected data will always be treated in accordance with current EU data protection legislation. By ticking the box (agree to the processing) below, you give your declaration of consent and assure that you have read the description of the study and questionnaire as well as agree to the data protection clause and terms and conditions described.

Thank you for your time and feedback!

CONTACT
Robert Philipp
European Project Center
Hochschule Wismar, University of Applied Sciences: Technology, Business and Design
E-Mail: robert.philipp[at]hs-wismar.de

If you would like to obtain more information about the processing of your personal data, please click here

☐ I agree to the processing of my personal data in accordance with the information provided herein

I don't want to participate

START THE SURVEY

LEAD PARTNER

PROJECT PARTNERS

INTERMARE | Interreg South Baltic | EUROPEAN UNION | European Regional Development Fund

Question 1:

Please identify the maritime sector your company operates in.

--- please select ---

Question 2:

In which country is your company located?

--- please select ---

Question 3:

In which year was your company founded?

--- please select ---

Question 4:

Please indicate the number of employees in your company at the end of 2018.

--- please select ---

20% CONTINUE

LEAD PARTNER: MTG Międzynarodowe Targi Gdańskie SA – Gdańsk International Fair Co.

PROJECT PARTNERS: Rostock Business | Klaipėda Chamber of Commerce, Industry and Crafts | Strategic Self-Management Institute | INOiK

INTERMARE | Interreg South Baltic | EUROPEAN UNION | European Regional Development Fund

Question 5:

Please, estimate your company's turnover growth rate (in %) for the next five years (2019 till 2023) according to the following geographical markets:

If you do not expect any turnover on one or more of the following geographical markets, please select "No turnover expected".

	Turnover growth rate in the next five years (2019 till 2023)
Regional	--- please select ---
National (incl. Regional)	--- please select ---
Baltic Sea Region (incl. National)	--- please select ---
Europe (incl. Baltic Sea Region)	--- please select ---
Africa	--- please select ---
Asia	--- please select ---
Australia	--- please select ---
North America	--- please select ---
South America	--- please select ---

40% CONTINUE

LEAD PARTNER: MTG Międzynarodowe Targi Gdańskie SA – Gdańsk International Fair Co.

PROJECT PARTNERS: Rostock Business | Klaipėda Chamber of Commerce, Industry and Crafts | Strategic Self-Management Institute | INOiK

Question 6:

How do you evaluate the influence of
digitalisation (Blockchain, Industrie 4.0, Big Data, Internet of Things, etc.),
the European Guidelines for the development of the TEN-T (Trans-European Transport Network) and
international regulations that affect business of maritime industry and related stakeholders (lastly particularly: IMO Marpol Annex VI, Baltic Sea Region as Sulphur Emission Control Area – SECA; Global Sulphur Cap 0,5% in year 2020 or 2025)
on the future business activities of your company?

Please select only one option per row.

	(-2) Very negative	(-1) Rather negative	(0) Neutral	(+1) Rather positive	(+2) Very positive	Not aware
Digitalisation	○	○	○	○	○	○
TEN-T	○	○	○	○	○	○
SECA Regulations & Global Sulphur Cap	○	○	○	○	○	○

Question 7:

In your opinion are there any other important internal or external market trends that might affect the business activities of your company in the future?

○ No

○ If yes, which?

Question 8:

Which opportunities (challenges) and threats (problems) might emerge for your company in the future (next five years: 2019 till 2023)?

Opportunities	
Threats	

60% CONTINUE

Question 9:

As a result of the upcoming digitalisation (Blockchain, Industrie 4.0, Big Data, Internet of Things, etc.) which new business activities, operations or other changes are planned in your company?

Please select all that apply.

- ☐ Additional administrative procedures / services
- ☐ Additional investments; if yes, estimate the total amount in Euro:
- ☐ Change in business operations / practices
- ☐ Dismissal of staff; if yes, estimate the number of employees:
- ☐ Purchase of new equipment
- ☐ Recruitment of new staff; if yes, estimate the number of employees:
- ☐ Staff training and / or retraining
- ☐ Value added activities
- ☐ None
- ☐ Other; if yes, please specify:

Question 10:

As a result of the TEN-T development (Trans-European Transport Network) which new business activities, operations or other changes are planned in your company?

Please select all that apply.

- ☐ Additional administrative procedures / services
- ☐ Additional investments; if yes, estimate the total amount in Euro:
- ☐ Change in business operations / practices
- ☐ Dismissal of staff; if yes, estimate the number of employees:
- ☐ Purchase of new equipment
- ☐ Recruitment of new staff; if yes, estimate the number of employees:
- ☐ Staff training and / or retraining
- ☐ Value added activities
- ☐ None
- ☐ Other; if yes, please specify:

Question 11:

As a result of the announced IMO MAROPOL Annex VI (SECA Regulations in Baltic Sea Region and Global Sulphur Cap 0,5% in year 2020 or 2025) which new business activities, operations or other changes are planned in your company?

Please select all that apply.

- ☐ Additional administrative procedures / services
- ☐ Additional investments; if yes, estimate the total amount in Euro:
- ☐ Change in business operations / practices
- ☐ Dismissal of staff; if yes, estimate the number of employees:
- ☐ Purchase of new equipment
- ☐ Recruitment of new staff; if yes, estimate the number of employees:
- ☐ Staff training and / or retraining
- ☐ Value added activities
- ☐ None
- ☐ Other; if yes, please specify:

80% CONTINUE

YOU HAVE SUCCESSFULLY COMPLETED THE SURVEY.

THANK YOU VERY MUCH FOR YOUR SUPPORT.

If you would like to ask any specific issues or have any other inquiries related to this questionnaire or the project, please feel free to contact any of the INTERMARE South Baltic project team members or the project Lead Partner.

CONTACT

Robert Philipp
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E-Mail: robert.philipp[at]hs-wismar.de

100%

LEAD PARTNER

PROJECT PARTNERS

Source: Compiled by author.

2. Online Survey: Digital Auditing in Small Ports

Connect2SmallPorts Project Team relies on You and Your feedback!

QUESTIONNAIRE ON DIGITAL AUDITING IN SMALL PORTS
in the frame of the EU project "Connect2SmallPorts – South Baltic Small Ports as Gateways towards Integrated Sustainable European Transport System and Blue Growth by Smart Connectivity Solutions", part-financed by the European Regional Development Fund (ERDF) within the Interreg South Baltic Programme 2014–2020.

PROJECT AND QUESTIONNAIRE FICHE
Connect2SmallPorts is a non-profit project that focuses on improving cross-border connectivity for a functional blue and green transport area. The project aims to enhance the quality and environmental sustainability of transport services in the South Baltic Sea area. Thereby, in particular, the project focalises real-life existing and not artificial problems of Blue Growth and targets at improving IT and infrastructural capacity of small ports in South Baltic Sea Region.
The aim of the questionnaire "Digital Auditing in Small Ports" is to analyse and index ports according to their performance and readiness for the digitalisation.

It takes you only 5 minutes to complete this questionnaire.

All participants, who completed the questionnaire, are invited to join for free one of the following study visits that are planned during the next two years (2020-2021) by the Connect2SmallPorts team (two persons per organisation/port):
- Singapore,
- Dubai,
- Valencia,
- Turku.
If you are interested to join one of the abovementioned study visits, please write an E-Mail to the contact person indicated on the last page of the survey.

DATA PROTECTION CLAUSE AND DECLARATION OF CONSENT
This declaration of consent asks you to allow the researcher to record and use your answers and information to enhance knowledge and understanding of the declared topic and research field mentioned above. Participation in this questionnaire is completely voluntary.
Data collected will be analysed and further processed in an aggregated form. All collected data will always be treated in accordance with current EU data protection legislation. By ticking the box below (i.e. agree to the processing), you give your declaration of consent and assure that you have read the description of the study and questionnaire as well as agree to the data protection clause and terms and conditions described.

Thank you for your time and feedback!

CONTACT
Project Leader
Robert Philipp
European Project Center
Hochschule Wismar, University of Applied Sciences: Technology, Business and Design
E-Mail: robert.philipp[at]hs-wismar.de

If you would like to obtain more information about the processing of your personal data, please click here

☐ I agree to the processing of my personal data in accordance with the information provided herein

I don't want to participate

START THE SURVEY

CONNECT2SMALLPORTS Interreg South Baltic EUROPEAN UNION European Regional Development Fund

General Section

What is the name of your port?

What is your contact E-Mail address?

13% CONTINUE

HOCHSCHULE WISMAR UNIVERSITY OF APPLIED SCIENCES TECHNOLOGY BUSINESS AND DESIGN

European Regional Development Fund

CONNECT2SMALLPORTS | Interreg South Baltic | EUROPEAN UNION

Digital performance measurement

Management

1. 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
○	○	○	○	○	○

2. 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
○	○	○	○	○	○

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

No innovation cooperations exist	Pilot initiatives are planned	Innovation cooperations are in development phase	Innovation cooperations are formulated and defined	Innovation cooperations are in implementation phase	Innovation cooperations are implemented
○	○	○	○	○	○

4. What is your share of digital investments (x) in relation to total investments?

$x \leq 10\%$	$10\% < x \leq 20\%$	$20\% < x \leq 30\%$	$30\% < x \leq 40\%$	$40\% < x \leq 50\%$	$x > 50\%$
○	○	○	○	○	○

BACK 25% CONTINUE

HOCHSCHULE WISMAR UNIVERSITY OF APPLIED SCIENCES TECHNOLOGY, BUSINESS AND DESIGN

CONNECT2SMALLPORTS
Interreg South Baltic
EUROPEAN UNION
European Regional Development Fund

Digital performance measurement

Human Capital

5. What is the proportion of employees with an IT educational background (x)?

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

6. 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	○	○	○	○	○	○

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

BACK 38% CONTINUE

HOCHSCHULE WISMAR

CONNECT2SMALLPORTS

Interreg South Baltic

EUROPEAN UNION

European Regional Development Fund

Digital performance measurement

Functionality (IT)

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

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

Very bad	Bad	Rather bad	Rather good	Good	Very good
○	○	○	○	○	○

BACK 50% CONTINUE

HOCHSCHULE WISMAR

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CONNECT2SMALLPORTS Interreg South Baltic EUROPEAN UNION European Regional Development Fund

Digital performance measurement

Technology

14. 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)	○	○	○	○	○	○

BACK 63% CONTINUE

HOCHSCHULE WISMAR UNIVERSITY OF APPLIED SCIENCES TECHNOLOGY BUSINESS AND DESIGN

CONNECT2SMALLPORTS

Interreg South Baltic

EUROPEAN UNION

European Regional Development Fund

Digital performance measurement

Information

15. 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	○	○	○	○	○	○

BACK 75% CONTINUE

HOCHSCHULE WISMAR

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Operational performance measurement

16. What is your (expected/estimated) cargo throughput and passenger transition/transit in 2019?

Cargo throughput (tonnes) =	
Passenger transition (no. of passengers) =	

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

	0 – 100	
Liquid bulk goods		0 %
Dry bulk goods		0 %
Containers		0 %
Ro-Ro mobile self-propelled units		0 %
Ro-Ro mobile non self-propelled units		0 %
Others not specified		0 %
Total		0 %

BACK 88% CONTINUE

HOCHSCHULE WISMAR University of Applied Sciences Technology, Business and Design

CONNECT2SMALLPORTS | Interreg South Baltic | EUROPEAN UNION | European Regional Development Fund

YOU HAVE SUCCESSFULLY COMPLETED THE SURVEY.

THANK YOU VERY MUCH FOR YOUR SUPPORT.

If you would like to ask any specific issues or have any other inquiries related to this questionnaire or the project, please feel free to contact any of the Connect2SmallPorts project team members or the project Lead Partner.

CONTACT

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100%

HOCHSCHULE WISMAR University of Applied Sciences Technology, Business and Design

Source: Compiled by author.

Curriculum vitae

Personal data

Name:	Robert Philipp
Date of birth:	27 March 1988
Place of birth:	Neubrandenburg (Germany)
Citizenship:	German

Contact data

E-mail:	rophil@taltech.ee robert.philipp@hs-wismar.de

Education

2016 – Until now	Tallinn University of Technology – PhD student
2011 – 2014	Hochschule Wismar, University of Applied Sciences: Technology, Business and Design – M.A.
2007 – 2011	Hochschule Wismar, University of Applied Sciences: Technology, Business and Design – B.A.
2000 – 2007	Johann Wolfgang von Goethe Gymnasium Pritzwalk – Abitur

Language competence

English	Reading (C2), Listening (C2), Speaking (C2), and Writing (C1)
French	Reading (C1), Listening (C1), Speaking (B2), and Writing (B2)
German	Mother Tongue

Professional employment

2015 – Until now

Hochschule Wismar, University of Applied Sciences: Technology, Business and Design

Research Associate for Lectures:

- Materials and production management / Logistics (Compulsory course)
  Bachelor:
  Business Administration (national)
  Business Informatics (national + international)
- Statistics (Compulsory course)
  Bachelor:
  Business Administration (national)
  Business Informatics (national)
- Market and location analysis (Elective course)
  Bachelor: Business Administration (national)

External Expert for European Project Centre (since 2016):

- INTERREG V A:
  Connect2SmallPorts (seed-money & subsequent main project), 2017 + 2018–2021
  INTERMARE South Baltic, 2017–2021
- INTERREG V B:
  TEST-4-SME, 2017–2020
  GoLNG, 2016–2019

Elulookirjeldus

Isikuandmed

Nimi:	Robert Philipp
Sünniaeg:	27. märts, 1988
Sünnikoht:	Neubrandenburg (Saksamaa)
Kodakondsus:	Saksamaa

Kontaktandmed

E-post:	rophil@taltech.ee robert.philipp@hs-wismar.de

Hariduskäik

2016 – praeguseni	Tallinna Tehnikaülikool – doktorant
2011 – 2014	Hochschule Wismar, Tehnoloogia, äri ja disaini rakenduskõrgkool – M.A.
2007 – 2011	Hochschule Wismar, Tehnoloogia, äri ja disaini rakenduskõrgkool – B.A.
2000 – 2007	Johann Wolfgang von Goethe Gymnasium Pritzwalk – keskharidus

Keelteoskus

Inglise keel	Lugemine (C2), Kuulamine (C2), Kõne (C2), Kirjutamine (C1)
Prantsuse keel	Lugemine (C1), Kuulamine (C1), Kõne (B2), Kirjutamine (B2)
Saksa keel	Emakeel

Teenistuskäik

2015 – praeguseni

Hochschule Wismar, Tehnoloogia, äri ja disaini rakenduskõrgkool

Uurija-lektori ametikohal loengute pidamine:

- Materjalid ja tootmiskorraldus / Logistika (kohustuslik kursus)
  Bakalaureause taseme tudengitele järgnevatel erialaldel:
  Ärikorraldus (riigisisene)
  Äriinformaatika (riigisisene ja rahvusvaheline)
- Statistics (kohustuslik kursus)
  Bakalaureause taseme tudengitele järgnevatel erialaldel:
  Ärikorraldus (riigisisene)
  Äriinformaatika (riigisisene)
- Turu- ja asukohaanalüüs (valikkursus)
  Bakalureuse tasemele erialal: Ärikorraldus (riigisisene)

Euroopa Projektikeskuse välisekspert (alates 2016):

- INTERREG V A:
  Connect2SmallPorts (algrahastus ja sellele järgnev põhiprojekt), 2017 + 2018–2021
  INTERMARE South Baltic, 2017–2021
- INTERREG V B:
  TEST-4-SME, 2017–2020
  GoLNG, 2016–2019

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