Digitization in maritime logistics — What is there and what is missing?

Markus Fruth* and Frank Teuteberg

Abstract: The global seaports are of pivotal importance for the world economy. Since 1990, global container traffic has grown by an average of 10% annually. Equally, the steady growth of ship sizes poses major logistical and technical problems worldwide. Given these facts, shipping and maritime logistics would largely benefit from Big Data as well as the emerging digital technologies. Apart from the many positive effects of digitization in maritime logistics with respect to efficiency, safety and energy saving, there are, however, also risks (e.g. data abuse, cybercrime). Based on a systematic literature review, this article provides an overview of the current state of digitization in maritime logistics, discusses existing problem areas, and shows potential for improvement. The results show that it is essential to capture the development potential in order to be able to benefit from the advantages. However, research is still in its initial stages, and there is a lack of theoretical and empirical work as well as explanatory approaches to appropriate recommendations for action and restructuring.

Subjects: Environment & Economics; IT Security; Hacking & Viruses; Management of IT; Computer Engineering; Information & Communication Technology (ICT); Communication Technology

Keywords: Big Data; digitization; maritime logistics; container terminal operations, port operations

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PUBLIC INTEREST STATEMENT

In maritime logistics, automation and digitization are constantly advancing, which noticeably affects all involved as business models and processes will change dramatically in the coming years. Against the background of the transformation process, this paper analyzes the status quo, discusses existing problem areas and identifies the arising future challenges. Furthermore, it provides recommendations for action in research and practice. A comprehensive and systematic literature analysis equally considering scientific and practical literature serves as a solid basis for this contribution. The results show that it is essential to identify the development potential in order to take full advantage of the opportunities in practice. However, research in this area is still in its initial stages. There is a lack of theoretical and empirical work as well as alternative explanatory approaches for appropriate recommendations for action and restructuring.
1. Introduction and motivation

Today, more than 90% of the world’s goods transport is handled by sea. Every year around 8 million tons of goods are transported across the sea by container ships, tankers, and bulk carriers (Göpfert & Braun, 2008). While in 2013 some 9.5 billion tons of sea freight have been loaded at seaports around the world, the total capacity of the global container fleet increased to approximately 20.5 million TEU in 2015 (Grote et al., 2016). Apart from the decline in 2009, which was due to the economic crisis, there has been a steady increase in the global container traffic every year. In view of the advancing globalization as well as the further progress in the containerization of general cargo transport, a further increase in container transport is expected (Fruth, 2016). Compared with the world gross domestic product and the world trade, sea trade has shown twice as fast growth in recent years. Container transport thereby accounts for less than a third, but was the fastest growing market segment within the maritime logistics sector (N.U., 2011). Maritime logistics is thus one of the key sectors for digital transformation. With its high degree of networking and its large number of interfaces, maritime logistics offers a broad range of applications for digital technologies. Therefore, digitization and logistics 4.0 provide a great potential for maritime shipping companies (Binder, 2016c). Traffic, port logistics, and just-in-time shipping will change as an electronic revolution takes shape with Big Data and the increasing networking of technologies (Berg & Hauer, 2015).

Already today large amounts of data are gathered on each individual ship, although most of them still remain unused. However, given the multitude of new digital business models, data usage will inevitably change within the coming years (Fruth, 2016). The International Maritime Organization (IMO) supports the introduction of electronic data exchange from ship to ship and from land to ship, to improve the efficiency, safety, and data security of navigation and communication (Berg & Hauer, 2015). For the ports and thus for the digital linking of complete value chains in maritime logistics, there are numerous developments in the area of Global Positioning System (GPS) navigation, more accurate ship arrival times, weather data in real-time feeds, and smart container technology to name only a few of the possibilities. Likewise, there is a mathematical model currently being developed that predicts earlier and more accurately ship arrival times, based on AIS, weather, tide, and maritime traffic data (Kuchta, 2016).

The interaction of all actors in the maritime supply chain as well as the sequence of the related processes is shown in Figure 1.

Figure 1. Interplay of the actors of the maritime supply chain.
The actors involved include senders, logistics providers (e.g. forwarders, port and terminal operators, and shipping companies) as well as the receivers. Some of the stakeholders (e.g. senders, recipients, shipping agents, traffic control centers, port operators, but also price regulation authorities, banks and transaction brokers) use new ICT (e.g. GPS navigation, electronic seacharts (ECDIS), RFID technologies, AIS and Big Data). In this way, the actors in the maritime transport chain, e.g. terminal operator, ship brokers, tugboats, pilots and forwarders, can bundle and, in case the time of arrival changes, adapt their resources appropriately (Fruth, 2016). Further, all parties concerned, e.g. the terminal operators, can be informed about the loaded goods prior to the ships' docking. Sea containers are equipped with radio-frequency identification (RFID) chips and thus become intelligent containers. Through smart containers and a suitable networking of single information systems, it is possible to fully digitize and globally network the entire maritime transport in order to render transparent the respective processes (Berg & Hauer, 2015). All terminal vehicles, machines and devices that are involved in the transportation, loading and unloading of goods are interconnected and communicate with each other, which is enabled by means of suitable information, communication and automation technologies. Such an inclusion in higher order systems leads to cyber-physical systems (Bai, Zhang, & Shen, 2010). In the case of forward and hinterland transport, the synchronous modality is based on the idea that the optimal transport mode and route combination can be selected based on real-time information. For example, the transport of smart containers is carried out depending on the respective availability of trucks, railcars, feeder ships or inland waterway vessels. Synchronous modality thus allows significant transport cost reductions and an optimum utilization of transport means while adhering to the respective delivery conditions (Lee et al. 2016). Based on the “Internet of Things” concept, machines and equipment on board ships can be equipped with sensors and transmitters that transmit performance data as well as early signs of errors to the ship computer via WiFi so that any necessary repairs or replacements of a defective system can be executed in the home port, which can save time as well as avoid considerable costs of flying technicians and parts to a ship in transit (Berg & Hauer, 2015).

In this paper, we address the following research questions (RQ):

RQ 1: What is the current status quo of digitization in maritime logistics?

RQ 2: What are the future challenges of digitization in maritime logistics?

To answer these research questions, a systematic literature analysis is carried out in various literature databases and specialist journals with the purpose to equally capture the scientific as well as practical status quo. The contribution at hand is structured as follows: In the second section, conceptual foundations and technologies in the area of digitization in the maritime logistics are discussed in order to obtain a primary basis. The third section describes the methodological approach. In the fourth section, the results of the literature analysis are presented in a concept matrix and recommendations for research and practice are given in a PESTEL matrix. The work concludes in section 5 with a final consideration, as well as implications for science and practice.

2. Background

New technologies and concepts such as big data, cloud computing, mobile computing or self-steering processes and services are more and more penetrating the areas of social life and are becoming increasingly important in economic processes. This results in the fourth industrial revolution linked to the term industry 4.0 (Broy, 2010, p. 17 ff). Industry 4.0 focuses on the linking of industrial processes and technologies, as well as the related business processes with the new information and communication technologies (ICT) (Keller, Pütz, & Siml, 2012). As in industry, the maritime sector also provides artificial intelligence to the digitized objects by means of programmability, storage capacity, sensors, and networking, which will allow an increase in the efficiency of ship operation (Bosse & Schwientek, 2011). With AIS-log files, weather data, and fuel-sampling data, large data sources are available to the shipping industry, which can be processed using big data analyses and
compared with other companies. In the field of maritime logistics, multimodal transport processes in the ports require an optimal networking of the individual actors who coordinate their activities in the transport chain in order to optimize traffic and goods flows (Berg & Hauer, 2015). With the use of Big Data and digital transformation, the fleet controls can be optimized, whereby costs are reduced and the environmental protection is improved. Traffic control and traffic flows can be optimized by using the ship’s operating data, thereby avoiding critical situations and thus reducing the risk of accidents. All ship data, e.g. machine, aggregate, weather and cargo data, are transmitted to the onshore management in real time, who can, if necessary, enter into a direct dialog with the ship’s management (Arndt, 2016). The current digital transformation is also regarded critically. Technology and information ethics ask for the gain and loss of personal and informational autonomy and the dependency of the customers on information technology and information companies. Moral and ethical problems arise, especially in the field of technology, information and economic ethics (Bendel, 2015). The digital transformation of maritime logistics is successful if the topics of data protection and data security are given a central role in the implementation strategy. The handling with digital applications and technologies does not only require competent users who are familiar with the digital innovations, but also secure systems that guarantee the protection of the company’s internal infrastructure and operating systems from cyberattacks (Schweer & Sahl, 2016).

3. Research approach
The present research contribution consists of a systematic literature analysis to identify the status quo of digitization in maritime logistics. The systematic literature analysis is employed, since in scientific research it is an adequate means to determine the current state of research (Fettke, 2006). It avoids redundant investigations and leads to important contributions in the corresponding research field. The three essential characteristics of a literature analysis are: systematics, explicitness, and reproducibility. The literature analysis in this article summarizes the research work on digitization in maritime logistics. For the analysis of the relevant literature, we decided on a concept matrix based on the five-step concept described by vom Brocke et al. (cf. Figure 2).
The definition of the investigation framework, the development of a research concept and the literature search with keyword search are described in the section **The literature analysis as a survey method: documentation**. The analysis and synthesis of the results of the literature analysis are given in **Table 1. Literature base and search results**. The total relevant contributions of scientific and practical literature are **124**.

| Databases                        | Results | Relevant | References |
|----------------------------------|---------|----------|------------|
| EBSCOhost (S)                    | 143     | 1        | De Tugny (2016) (1) |
| Science Direct (S)               | 223     | 16       | Lind, Hägg, Siwe, and Haroldson (2016) (1), An et al. (2016) (2), Yao Yu and ChangChuan (2011) (3), Haroldson (2015) (4), Cisic, Hadzic and Tigan (2009) (5), Martin-Soberon, Montfort, Sapina, Montede, and Calduch (2014) (6), Bechtis, Tosalikis, Vlachas, and Isakovou (2016) (7), Christiansen, Fagerholt, Nygreen, and Ronen (2013) (8), Sumbare, Perakovic, and Jurcevic (2015) (9), Paarafits (2016) (10), Stevens et al. (2015) (11), Cheng, Lai, and Sarks (2015) (12), Dadarzani, Fahimnia, Bell, and Sarks (2016) (13), Von Lukas (2010) (14), Cho, Roh, and Lee (2010) (15), Back, Lee, Shin, and Woo (2016) (16) |
| Taylor & Francis Online (S)      | 129     | 5        | Paulis, Paulis, and Dooley (2013) (16), Lee et al. (2016) (17), Cane, Cleophas, and Semeijn (2016) (18), Chysiosiolis, Makris, Xanthakis, and Mourtiz (2004) (19), Banomyong (2005) (20) |
| Google Scholar (S)               | 647     | 10       | An et al. (2016) (21), Biccario, Annese, and de Vanuto (2014) (22), Diwan (2015) (23), Karlsson, Haroldson, and Holmberg (2015) (24), Min (2008) (25), Lam (2011) (26), Acciaio and Wilmsmeyer (2015) (27), Van Leeuwen (2015) (28), Wu, van Leeuwen, and van Koppen (2012) (29), Sen (2016) (30) |
| SpringerLink (S)                  | 3393    | 9        | Bruer, Karsten, and Pisinger (2016) (31), Yang et al. (2016) (32), Haasis, Landwehr, Kille, and Obsadny (2014) (33), Isias and Duarte Macedo (2007) (34), Kim, Huh, and Kim (2016) (35), Lee and Lee (2016) (36), Jiang, Chew, and Lee (2014) (37), Xiang (2010) (38), Bendel (2015) (39) |
| International Journal of Innovation and Sustainable Development (S) | 235     | 0        | Grazia Speranza (2016) (40) |
| European Journal of Operations Research (S) | 49     | 1        | Gharehgozli, Roy, and de Koster (2016) (41), Kim et al. (2016) (42) |
| Maritime Economics & Logistics (S) | 425     | 2        | Gharehgozli, Roy, and de Koster (2016) (41), Kim et al. (2016) (42) |
| Maritime Policy & Management (S)  | 129     | 5        | Birchnell (2016) (43), Lee, Park, and Lee (2003) (44), Jafari, Taghavifard, Rouhani, and Moalagh (2010) (45), Roubouktsos et al. (2005) (46), Keceli (2011) (47) |
| Asian Journal of Shipping (S)     | 156     | 0        | 0 |
| International Journal of Shipping and Transport Logistics (S) | 222     | 2        | Prokop (2012) (48), Harder and Vaß (2012) (49) |
| Asia Insurance Review (S)         | 36      | 1        | Berg and Hauer (2015) (50) |
| THB – Deutsche Schiffahrts-Zeitung (P) | 379   | 11       | Fabarius (2017a) (51), Fabarius (2017b) (52), Fabarius (2017c) (53), Arndt (2017) (54), Binder (2016a) (55), Binder (2016b) (56), Binder, Oldenburg, and Breuer (2017) (57), Luders (2016) (58), Kleinart (2017) (59), Germann (2017) (60) |
| Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik (S) | 73      | 7        | N.U. (2016a) (61), Bruhn (2017) (62), Kretschmann and Schlegel (2016) (63), Von Lukas (2017) (64), Von Lukas (2016) (65), Von Lukas, Staack, and Köhler (2016) (66), N.U. (2016b) (67) |
| DNV – Deutsche Verkehrs-Zeitung (S) | 341    | 12       | Reimann (2017) (68), Naumann (2017a) (69), Granzow (2017) (70), De Jong (2017a) (71), De Jong (2017b) (72), Naumann (2016) (73), Naumann and Reimann (2016) (74), De Jong (2016) (75), Zapp (2015) (76), Naumann (2014) (77), Naumann (2017a) (78), Klass (2016) (79) |
| HANSA – International Maritime Journal (P) | 201   | 14       | N.U. (2017) (80), Selzer (2017a) (81), Selzer (2017b) (82), Selzer (2017c) (83), Meyer (2017) (84), Kuster (2017) (85), Leira (2016) (86), Selzer (2016) (87), Meyer (2016) (88), Bertram (2011) (89), Bertram (2017) (90), Bertram (2015) (91), Hochhaus (2011) (92) |
| Maritime Logistics Professional (P) | 357    | 4        | Doyle (2017) (93), Keefe (2017) (94), Keefe (2016) (95), Keefe (2014) (96) |
| Maritime Reporter and Engineering News (P) | 3128  | 24       | Muccin (2015) (97), Trauthwein (2017a) (98), Trauthwein (2017b) (99), Bays (2017) (100), Berge (2017) (101), Gruczna (2017) (102), Pekkanen (2017) (103), Pribyl (2016) (104), Segercrantz (2016a) (105), Muccin (2016) (106), Stoichevski (2016) (107), Haun (2015) (108), Segercrantz (2016b) (109), Hartmann and Remick (2015) (110), Rhodes and Soccoli (2015) (111), Segercrantz (2015a) (112), Weigel and Singleton (2014) (113), Bryant (2017) (114), Haynes (2016) (115), Stoichevski (2015) (116), Driver (2015) (117), Segercrantz (2015b) (118), Buda (2013) (119), Trauthwein (2013) (120) |
| Total relevant contributions of scientific and practical literature: | 124     | 0        | 0 |

The definition of the investigation framework, the development of a research concept and the literature search with keyword search are described in the section **The literature analysis as a survey method: documentation**. The analysis and synthesis of the results of the literature analysis are given in **Table 1. Literature base and search results**.
in the sections Results and Discussion. Finally, limitations are discussed in the section Conclusion and a final Closing Considerations and Implications for Science and Practice are given in the last section.

3.1. **Definition of scope of investigation**

According to vom Brocke et al., the classification scheme for literature searches, according to Cooper (1988) with six features, is suitable as a tried-and-tested tool and is shown in Figure 3. The highlighted fields illustrate the scope of this paper. The focus lies on the identification of the available literature, shows its degree of coverage, and cites from the identified literature.

3.2. **Research concept**

According to the definition of the scope of the investigation, the search concept has to be explained. First, the keywords used for the search are named, then the selection of the literature databases and magazine libraries is explained and subsequently the quantitative results of the literature search are presented. The keyword search was performed in the databases EBSCOhost, ScienceDirect, Taylor & Francis Online and SpringerLink. In order to reach a wide base of literature, we completed the search through the service Scholar of the search engine Google. The EBSCO literature database was used to search for scientific journals as well as specialist magazines from maritime transport and logistics. For high-quality contributions, “A”-based journals, which are not listed in EBSCO, were considered according to VHB-Jourqual3 part ranking logistics. In addition, a supplementary manual search was carried out in the specific journals of the International Journal of Innovation and Sustainable Development, European Journal of Operations Research, Maritime Economics & Logistics, Maritime Policy & Management, Asian Journal of Shipping, International Journal of Shipping and Transport Logistics and Asia Insurance Review. Furthermore, an additional manual search was carried out for the analysis of practical literature in the following journals, newspapers and reports: Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik, DVZ – Deutsche Verkehrszeitung, THB – Deutsche Schifffahrt’s Zeitung, HANSA International Maritime Journal, Maritime Logistics Professional and Maritime Reporter and Engineering News. The following keyword combinations were used in the search engines of the literature databases, the specialist journals and the practical literature: <(Digital*) AND (Maritime* Logistics)>, <(Big Data) AND (Maritime* Logistics)>, <(Digital*) AND (Shipping Industry)>, <(Digitalisation OR Digitalization OR Digitization) AND (Maritime* Logistics)>, <(Digital Transformation) AND (Maritime* Logistics)> as well <(Big Data) AND (Maritime* Logistics) AND (Maritime* Transportation)>. For all identified contributions from science and practice, we additionally carried out a forward and backward search, which led to three further papers. Although we specifically searched in the listed journals and magazines, in a next step we conducted an additional open Google search (forward and backward search) to broaden the search frame.

Table 1 shows the search results using all keyword combinations in the respective sources. The information in brackets behind the respective sources indicates the source of literature (P for practice and S for science).

A source is considered as relevant when it deals with digitization or transformation technologies in the maritime logistics. The review was executed by sorting the contributions by title, keywords and the abstract. After reading title and content specification, we decided whether or not we further analyze a contribution by reviewing the content or the abstract. A total of 124 contributions were identified as relevant and analyzed closer. Table 2 shows the list of publications title, grouped by major topic and subtopic(s).
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| De Tugry (2016) (1)                           | Offshore Magazine | Digital technology to transform AIMS | Automation   | Digital technology |
|                                             |                   |                  | Big Data    | Transform aims |
|                                             |                   |                  | Simulation and modelling | Technologies to transform aims |
|                                             |                   |                  | Software    | Communication technology |
|                                             |                   |                  |            | AIS |
|                                             |                   |                  |            | GPS-navigation |
|                                             |                   |                  |            | Routeplanning |
|                                             |                   |                  |            | ETA |
| Lind et al. (2016) (2)                        | Transportation Research Procedia – 6th Transport Research Arena | Sea Traffic Management – Beneficial for all Maritime Stakeholders | Automation   | Cloud-based eBusiness |
|                                             |                   |                  | Big Data    | Community stakeholders |
|                                             |                   |                  |            | Automation in seaports |
|                                             |                   |                  | Simulation and modelling | Transformation and modelling |
|                                             |                   |                  | Software    | VTS |
|                                             |                   |                  |            | AIS |
|                                             |                   |                  |            | GPS-navigation |
|                                             |                   |                  |            | Routeplanning |
|                                             |                   |                  |            | ETA |
| Carlan, Sys and Vanelslander (2016) (3)      | Research in Transportation Business & Management | How port community systems can contribute to port competitiveness: Developing a cost-benefit framework | Automation   | Alarm system |
|                                             |                   |                  | Big Data    | Research and development |
|                                             |                   |                  | Simulation and modelling | Cloud-based eBusiness |
|                                             |                   |                  | Software    | Competitive advantages |
|                                             |                   |                  |            | Cost-benefit analysis |
|                                             |                   |                  |            | Legislation on competitive advantages |
|                                             |                   |                  | Sustainable Maritime Transport | Development in supply chain |
|                                             |                   |                  |            | Smart container strategies and research |
| Yao Yu and ChangChuan (2011) (4)             | Procedia Engineering | A preliminary scheme of the online monitoring system for the ship discharging pollution at harbour based on AIS information | Automation   | Alarm system |
|                                             |                   |                  | Big Data    | Energy optimization |
|                                             |                   |                  | Simulation and modelling | Development simulation |
|                                             |                   |                  | Software    | AIS |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Haroldson (2015) [5] | 21st Americas Conference on Information Systems (AMCIS) | Digitalization of sea transports – enabling sustainable multi-modal transports | Automation | Alarm system, Energy optimization, Software, Sustainable transport models, Sustainable maritime transport, Green port operations |
| Cisic et al. (2009) [6] | MIPRO 2009, 32nd International Convention | The economic impact of e-Business in seaport systems | Automation | Cloud-based eBusiness, Big Data, Economic impacts |
| Martin-Soberon et al. (2014) [7] | Procedia – Social and behavioral sciences | Automation in port container terminals | Automation | Control monitoring, Automatisation in supply chains, Cloud-based eBusiness, Automatisation in seaports |
| Bechtis et al. (2016) [8] | Journal of Cleaner Production | Sustainable supply chain management in the digitalisation era: the impact of automated guided vehicles | Automation | Automatisation in seaports, Automatisation in supply chains, Energy optimization, Big Data, Networking, Sensor-chip-technology, Impact on maritime logistics |
| Christiansen et al. (2013) [9] | European Journal of Operations Research | Ship routing and scheduling in the new millenium | Big Data | Fleet optimization, Networking, Shiptraffic, ETA, Software | AIS, GPS-navigation, Routeplanning, ETA, Sustainable Maritime Transport, ETA |
| Sumic et al. (2015) [10] | Procedia Engineering | Optimizing Data Traffic Route for Maritime Vessels Communications | Automation | Control monitoring, Big Data | Fleet optimization, Reporting, Simulation and Modelling, VTS |
| Psaraftis (2016) [11] | Transportation Research Procedia, 6th Transport Research Arena | Green maritime logistics: the quest for win-win-solutions | Big Data | Research to reduce emissions, Sustainable Maritime Transport, Green supply chain, Energy efficiency |
| Stevens et al. (2015) [12] | Research in Transportation Business & Management | Is new emission legislation stimulation the implementation of sustainable and energy-efficient maritime technologies? | Automation | Energy optimization, Big Data | Air quality, Atmospheric environment, Sustainable Maritime Transport, Reduction of emissions, Green shipbuilding industry, Emissions |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Cheng et al. (2015) (13)                    | Transportation Research Part E: Logistics and Transportation Review | Sustainability in maritime supply chains: Challenges and opportunities for theory and practice | Sustainable Maritime Transport | Green supply chain, Energy efficiency, Green port operations, Research studies |
| Davarzani et al. (2016) (14)               | Transportation Research Part D: Transport and Environment | Greening ports and maritime logistics: A review | Big Data | Air quality, Atmospheric environment, Sustainable Maritime Transport, Reduction of emissions, Energy efficiency, Green port operations |
| Von Lukas (2010) (15)                      | 8th IFAC Conference on Control Applications in Marine Systems | Virtual and augmented reality for the maritime sector – applications and requirements | Simulation and modelling | Production processes, Software, Simulation and research |
| Cha et al. (2010) (16)                     | Journal of Robotics and Computer-Integrated Manufacturing | Integrated simulation framework for the process planning of ships and offshore structures | Simulation and modelling | Optimization, Simulation |
| Back et al. (2016) (17)                    | International Journal of Naval Architecture and Ocean Engineering | A study for production simulation model generation system based on data model at a shipyard | Automation | Research and development, Simulation and modelling, Optimization, Simulation, Simulation studies |
| Poulis et al. (2013) (18)                  | The Service Industries Journal | Information communication technology – innovation in a non-high technology sector: achieving competitive advantage in the shipping industry | Big Data | Cloud computing, Sustainable cost-reduction, VOIP, Competitive advantages, Legislation on competitive advantages, Real-time |
| Lee et al. (2016) (19)                     | Maritime Policy & Management | Port e-Transformation, customer satisfaction and competitiveness | Software | AIS, GPS-navigation, Routeplanning, ETAX |
| Caniels et al. (2016) (20)                 | Maritime Policy & Management | Implementing green supply chain practices: An empirical investigation in the shipbuilding industry | Big Data | Implementation of green supply chain practices, Sustainable Maritime Transport, Green shipbuilding industry, Implementing |
| Chyssolouris et al. (2004) (21)            | International Journal of Computer Integrated Manufacturing | Towards the Internet-based supply chain management for the ship repair industry | Automation | Supply chain management, Software, Control systems |

(Continued)
## Table 2. (Continued)

| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|-------------------|-------------|-------------|
| Banomyong (2005) (22) | Maritime Policy & Management | The impact of port and trade security initiatives on maritime supply-chain management | Automation | Automatisation in supply chains |
| | | | Big Data | Sensor-chip-technology |
| | | | | Impact on maritime logistics |
| | | | Simulation and modelling | Technology development |
| | | | Software | AIS |
| | | | | GPS-navigation |
| | | | | Routeplanning |
| | | | | ETA |
| An et al. (2016) (23) | 22nd Americas Conference on Information Systems (AMCIS) | Configuring Value with Service-Dominant Logic: the Case of Marine Informatics Technology | Automation | Research and development |
| | | | Simulation and modelling | Simulation studies |
| | | | Sustainable Maritime Transport | Real-time tracking of global aid transports |
| Biccario et al. (2014) (24) | TETHYS 2014 – Toward Emerging Technology for Harbour systems and Services | Wireless Remote Environmental Monitoring and Control of Perishable Goods in Maritime Transportation | Automation | Cloud-based eBusiness |
| | | | Big Data | Fleet optimization |
| | | | | Cloud-based eBusiness |
| | | | Software | Services for port systems |
| | | | Sustainable Maritime Transport | Smart container (RFID technology) |
| | | | | Real-time control of perishable cargo |
| | | | | Conditions of cargo (RFID) |
| | | | | Smart container strategies and research |
| Diwan (2015) (25) | The International Maritime & Logistics Conference (MARLOG 4) | Cloud community in e-clusters: Towards sustainable logistics clusters | Automation | Energy optimization |
| | | | Big Data | Fleet optimization |
| | | | Sustainable Maritime Transport | Sustainable maritime transport |
| | | | | Logistics clusters |
| Karlsson et al. (2015) (26) | 21st Americas Conference on Information Systems (AMCIS) | Co-using Infrastructure for Sustainable in Maritime Transports | Automation | Energy optimization |
| | | | Big Data | Infrastructure |
| | | | Sustainable Maritime Transport | Sustainable maritime transport |
| | | | | Green port operations |
| | | | | Green shipbuilding industry |
| | | | | Legislation infrastructure |
| Min (2008) (27) | IFAC Proceedings of the 17th World Congress | Automation and Control Systems Technology in Korean Shipbuilding Industry: The State of the Art and die Future Perspectives | Automation | Control system |
| | | | | Research and development |
| | | | Big Data | Control systems |
| | | | Software | Control systems |
| Author, year of publication, reference number | Publication outlet                  | Publication title                                                                 | Major topic                  | Subtopic(s)                                                                 |
|----------------------------------------------|-------------------------------------|------------------------------------------------------------------------------------|------------------------------|----------------------------------------------------------------------------|
| Lam (2011) [28]                              | Journal of Transport Geography      | Patterns of maritime supply chains: Slot capacity analysis                         | Automation                   | Automatisation in supply chain                                            |
|                                              |                                     |                                                                                    |                              | Automatisation in seaports                                                 |
|                                              |                                     |                                                                                    | Big Data                     | Real-time                                                                  |
|                                              |                                     |                                                                                    |                              | Cloud-computing                                                            |
|                                              |                                     |                                                                                    |                              | VOIP                                                                       |
|                                              |                                     |                                                                                    |                              | Sustainable cost-reduction                                                 |
|                                              |                                     |                                                                                    |                              | Cloud-based eBusiness                                                      |
|                                              |                                     |                                                                                    |                              | Control systems                                                            |
|                                              |                                     |                                                                                    | Software Control systems     | Control systems                                                            |
| Acciaro and Wilmsmeier (2015) [29]           | Research in Transportation Business & Management | Energy efficiency in maritime logistics chains                                      | Sustainable Maritime Transport | Green supply chain                                                         |
|                                              |                                     |                                                                                    |                              | Green port operations                                                      |
|                                              |                                     |                                                                                    |                              | Energy efficiency                                                          |
| Van Leeuwen (2015) [30]                      | Ocean & Coastal Management          | The regionalization of maritime governance: Towards a polycentric governance system for sustainable shipping in the European Union | Big Data                     | Air quality                                                                |
|                                              |                                     |                                                                                    |                              | Atmospheric environment                                                    |
|                                              |                                     |                                                                                    | Sustainable Maritime Transport | Sustainable maritime transport                                             |
|                                              |                                     |                                                                                    |                              | Governance                                                                 |
| Wuisan et al. (2012) [31]                    | Marine Policy                       | Greening international shipping through private governance: A case study of the Clean Shipping Project | Big Data                     | Air quality                                                                |
|                                              |                                     |                                                                                    |                              | Atmospheric environment                                                    |
|                                              |                                     |                                                                                    | Sustainable Maritime Transport | Reduction of emissions                                                     |
|                                              |                                     |                                                                                    |                              | Sustainable maritime transport                                             |
|                                              |                                     |                                                                                    |                              | Development in supply chain                                               |
|                                              |                                     |                                                                                    |                              | Governance                                                                 |
| Sen (2016) [32]                              | Maritime Security (2nd Edition)     | Cyber and Information Threats to Seaports and Ships                                 | Risks                        | Cyber-attacks                                                              |
|                                              |                                     |                                                                                    |                              | Terrorist attacks                                                          |
| Brouer et al. (2016) [33]                    | Emrouznejad, A. (ed.) Big Data Optimization: Recent Developments and Challenges | Big Data Optimization in Maritime Logistics                                         | Big Data                     | Fleet optimization                                                         |
|                                              |                                     |                                                                                    |                              | Shipping traffic                                                           |
|                                              |                                     |                                                                                    |                              | Reporting                                                                  |
|                                              |                                     |                                                                                    |                              | ETA                                                                        |
|                                              |                                     |                                                                                    |                              | Optimization of administrative procedures                                  |
|                                              |                                     |                                                                                    | Simulation and modelling      | VTS                                                                        |
|                                              |                                     |                                                                                    | Software                      | AIS                                                                        |
|                                              |                                     |                                                                                    |                              | GPS-navigation                                                             |
|                                              |                                     |                                                                                    |                              | Routeplanning                                                             |
|                                              |                                     |                                                                                    |                              | ETA                                                                        |
|                                              |                                     |                                                                                    | Sustainable Maritime Transport | ETA                                                                        |
|                                              |                                     |                                                                                    |                              | Smart container strategies and research                                    |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|-------------------|-------------|-------------|
| Yang et al. (2016) (34)                     | Peer-to-Peer - Networking and Applications | Resource allocation in cooperative cognitive radio networks towards secure communications for maritime big data systems | Big Data | Ship operating Machine / aggregate Fleet optimization Simulation and modelling VTS Software AIS GPS-navigation ETA Control systems |
| Haasis et al. (2014) (35)                   | Dethloff, J., Haasis, H. D., Koper, H., Kotzab, H., Schönberger, J. (eds.) Logistics Management | Cloud-Based eBusiness Standardization in the Maritime Supply Chain | Automation | Cloud-based eBusiness Big Data Networking Real-time Cloud-computing VOIP Sustainable cost-reduction Reporting |
| Isaias and Duarte Macedo (2007) (36)       | Smith, M. J., Salvendy, G. (eds.) Human Interface and the Management of Information | Web services as a solution for maritime port information interoperability | Automation | Cloud-based eBusiness Big Data Shiptraffic ETA Web services Software ETA Services for port systems Sustainable Maritime Transport ETA |
| Kim, Huh et al (2016) (37)                 | Kim, K. J., Joukov, N. (eds.) Information Science and Applications (ICISA) | Design and Implementation of Drone for Wideband Communication and Long-range in Maritime | Big Data | Real-time Cloud-computing VOIP Sustainable cost-reduction Simulation and Modelling Communication |
| Lee and Lee (2016) (38)                    | Lee, P. T. W., Cullinane, K. (eds.) Dynamic Shipping and Port Development in the Globalized Economy | New Concepts in the Economics of Flow, Connection, and Fusion Technology in Maritime Logistics | Simulation and Modelling | Development in new technologies Software AIS GPS-navigation Routeplanning ETA |
| Jiang et al. (2014) (39)                   | Lee, C. Y., Meng, Q. (eds.) Handbook of Ocean Container Transport Logistics | Innovative Container Terminals to Improve Global Container Transport Chains. | Automation | Automatisation in supply chains Infrastructure Sustainable maritime transport Smart container (RFID technology) Conditions of cargo (RFID) Simulation and modelling Technology development |
| Xiang (2010) (40)                          | Marine Science & Technology in China: A Roadmap to 2050 | Status and Opportunities of Chinese Marine Science & Technology Development | Simulation and modelling | Technology development Simulation (Continued) |
### Table 2. (Continued)

| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|--------------------|------------------|-------------|-------------|
| Bendel (2015) (41)                          | HMD Praxis der Wirtschafts-informatik | Die Industrie 4.0 aus ethischer Sicht | Risks | Loss of workplaces, Digital ethical risks, Social risks |
| Grazia Speranza (2016) (42)                | European Journal of Operations Research | Trends in transportation and logistics | Simulation and modelling | Technology development, Sustainable maritime transport, Energy efficiency |
| Gharehgozli et al. (2016) (43)             | Maritime Economics & Logistics | Sea container terminals: New technologies and OR models | Automation | Cloud-based eBusiness, New port facilities, Simulation, Development in new technologies |
| Kim et al. (2016) (44)                     | Maritime Economics & Logistics | The impact of RFID utilization and supply chain information sharing on supply performance: Focusing on the moderating role of supply chain culture | Sustainable maritime transport | Smart container (RFID technology), Conditions of cargo (RFID), Smart container strategies and research, Real-time tracking of global aid transports |
| Birtchnell (2016) (45)                     | Applied Mobilities Journal | The missing mobility: friction and freedom in the movement and digitization of cargo | Software | Cargodata, Real-time control of perishable cargo, Conditions of cargo (RFID), Smart container strategies and research |
| Lee et al. (2003) (46)                     | Maritime Policy & Management | A simulation study for the logistics planning of a container terminal in view of SCM | Automation | Research and development, New port facilities, Development, Simulation studies |
| Jafari et al. (2010) (47)                  | Maritime Policy & Management | E-commerce development experiences in world’s leading container ports and offering a model for Shahid Rajaee Port | Automation | Research and development, New port facilities, Development in new technologies, Simulation |
| Roumboutsos et al. (2005) (48)            | Maritime Policy & Management | Information technology network security risk assessment and management framework for shipping companies | Big Data | Networking, Risk assessment and management, Data misuse, Sabotage, Cyber-attacks, Terrorist attacks |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Keceli (2011) (49) | Maritime Policy & Management | A proposed innovation strategy for Turkish port administration policy via information technology | Automation | Automatisation in supply chains |
| | | | Big Data | Port administrations |
| | | | Simulation and Modelling | Innovation strategies for future port administrations |
| | | | | Administrations |
| Prokop (2012) (50) | International Journal of Shipping and Transport Logistics | Smart containers and the public goods approach to supply chain security | Sustainable Maritime Transport | Green supply chain |
| | | | Smart container (RFID technology) | Energy efficiency |
| | | | Green port operations | Conditions of cargo (RFID) |
| | | | Real-time tracking of global aid transports | Risks |
| | | | | Cyber-attacks |
| | | | | Research on the risks of security of the supply chain |
| | | | | Security of the supply chain |
| Harder and Voß (2012) (51) | International Journal of Shipping and Transport Logistics | A simple RFID cost model for the container shipping industry | Sustainable maritime transport | Smart container (RFID technology) |
| | | | Conditions of cargo (RFID) | Smart container strategies and research |
| | | | Real-time tracking of global aid transports | Risks |
| | | | | Cyber-attacks |
| | | | | Research on the risks of security of the supply chain |
| Berg and Hauer (2015) (52) | Asia Insurance Review | Digitalisation in shipping and logistics | Risks | Loss of workplaces |
| | | | | Digital ethical risks |
| | | | | Social risks |
| | | | | Abolition of workplaces |
| Fabarius (2017a) (53) | THB – Deutsche Schifffahrts-Zeitung | Maritime Wirtschaft erfindet sich neu | Automation | Automatisation in supply chains |
| | | | Supply chain management | |
| | | | Big Data | Control systems |
| | | | Risks | Cyber-attacks |
| | | | | Terrorist attacks |
| Fabarius (2017b) (54) | THB – Deutsche Schifffahrts-Zeitung | Digitale Häfen brauchen mehr Sicherheit | Risks | Cyber-attacks |
| | | | | Terrorist attacks |
| Fabarius (2017c) (55) | THB – Deutsche Schifffahrts-Zeitung | Digitalisierung braucht rechtlichen Rahmen | Big Data | Legislation on competitive advantages |
| | | | Risks | Data misuse |
| | | | | Security of the supply chain |
| Arndt (2017) (56) | THB – Deutsche Schifffahrts-Zeitung | Digitalisierung bedingt auch Investitionen | Big Data | Cost-benefit analysis |
| | | | Simulation and modelling | Development in new technologies |
| Binder (2016a) (57) | THB – Deutsche Schifffahrts-Zeitung | AK Küste: CyberSicherheit verbessern | Risks | Data misuse |
| | | | | Security of the supply chain |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Binder (2016b) (58)                         | THB – Deutsche Schifffahrts-Zeitung | VDR: Reeder packen Digitalisierung | Automation | Automatisation in supply chains, Digital technology, Big Data, Fleet optimization, Control systems, Software, Communication technology, GPS-navigation, Routeplanning, ETA |
| Binder (2017) (59)                          | THB – Deutsche Schifffahrts-Zeitung | Chancen für smart shipping und Big Data | Big Data | Cloud-based eBusiness, Ship operating, Machine/Aggregate, Sensor-chip-technology, Impact on maritime logistics, Simulation and Modelling, Development, Simulation |
| Binder et al. (2017) (60)                   | THB – Deutsche Schifffahrts-Zeitung | Die ‘Tesla’ der Meere wird ein Boxcarrier | Automation | Autonomous / smart shipping, Big Data, Risk assessment and management, Autonomous / smart shipping |
| Lüders (2016) (61)                          | THB – Deutsche Schifffahrts-Zeitung | Digitalisierung reduziert Kosten | Big Data | Competitive advantages, Economic impacts, Sustainable maritime transport, Energy efficiency, Reduction of emissions |
| Kleinort (2017) (62)                        | THB – Deutsche Schifffahrts-Zeitung | Daten-Plattform für maritime Branche | Automation | Control system, Research and development, Big Data, Cloud-based eBusiness, Port administration, Web services, Reporting, Software, Simulation and research |
| Germann (2017) (63)                         | THB – Deutsche Schifffahrts-Zeitung | Schifffahrt trifft Raumfahrt | Big Data | Sensor-chip-technology, Impact on maritime logistics |
| N.U. (2016a) (64)                           | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | Prozessoptimierung durch Digitalisierung im Seehafenumschlag | Automation | Automation in seaports, Big Data, Port administration, Control systems, Software, Services for port systems, Cargodata |
| Bruhn (2017) (65)                           | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | Maritime Wirtschaft – an der Schwelle zur autonomen Schifffahrt | Automation | Autonomous / smart shipping, Big Data |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|--------------------------------------------|-------------------|-----------------|-------------|-------------|
| Kretschmann and Schlegel (2016) (66)       | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | Service 4.0 als Chance für die maritime Zulieferindustrie | Big Data | Ship operating, Machine/aggregate, Networking, Economic impacts |
|                                            |                   |                 | Software | Service for port systems |
|                                            |                   |                 | Sustainable maritime transport | Green shipbuilding industry |
| Von Lukas (2017) (67)                      | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | Maritime Data Space: Mehrwert durch sichere Verknüpfung von Daten | Big Data | Sensor-chip-technology, Impact on maritime logistics, Economic impacts, Infrastructure |
|                                            |                   |                 | Software | Technology development |
| Von Lukas (2016) (68)                      | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | Zur Rolle des Menschen in der Zukunftsvision 4.0 | Automation | Cloud-based, eBusiness, Control monitoring, Control system |
|                                            |                   |                 | Big Data | Real-time, Cloud-computing, VOIP, Sustainable cost-reduction, Networking, Optimization of administrative procedures |
|                                            |                   |                 | Simulation and modelling | Administration, Communication |
| Von Lukas et al. (2016) (69)               | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | 3D-Technologie als Grundlage für die digitale Transformation der maritimen Wirtschaft | Simulation and modelling | Simulation studies, Production processes, Optimization simulation |
|                                            |                   |                 | Sustainable maritime transport | Green shipbuilding industry |
|                                            |                   |                 | Software | |
| N.U. (2016b) (70)                          | Schiff&Hafen – Internationale Fachzeitschrift für Schifffahrt und maritime Technik | Technology Outlook 2025: Ausblick auf die Schifffahrt der Zukunft | Automation | Autonomous / smart shipping, Sensor-chip-technology, Impact on maritime logistics |
|                                            |                   |                 | Big Data | Autonomous / smart shipping, Sensor-chip-technology, Impact on maritime logistics |
|                                            |                   |                 | Sustainable maritime transport | Green supply chain, Reduction of emissions, Green shipbuilding industry |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Reimann (2017) [71]                         | *DVZ – Deutsche Verkehrs-Zeitung* | Ab 2020 werden Schiffe ferngesteuert | Automation | Autonomous / smart shipping |
|                                             |                   |                  | Big Data | Sensor-chip-technology |
|                                             |                   |                  |          | Impact on maritime logistics |
|                                             |                   |                  |          | Autonomous / smart shipping |
|                                             |                   |                  | Software | AIS |
|                                             |                   |                  |          | GPS-navigation |
|                                             |                   |                  |          | Routeplanning |
|                                             |                   |                  |          | ETA |
| Naumann (2017a) [72]                        | *DVZ – Deutsche Verkehrs-Zeitung* | Digitale Modelle setzen sich durch | Automation | Automatisation in supply |
|                                             |                   |                  | Big Data | Sensor-chip-technology |
|                                             |                   |                  |          | Impact on maritime logistics |
|                                             |                   |                  |          | Control systems |
|                                             |                   |                  | Simulation and modelling | Development in new technologies |
|                                             |                   |                  | Sustainable maritime transport | Conditions of cargo (RFID) |
| Granzow (2017) [73]                         | *DVZ – Deutsche Verkehrs-Zeitung* | Maritime Logistik wird digitaler | Automation | Automation in supply chain management |
|                                             |                   |                  | Big Data | Fleet optimization |
|                                             |                   |                  |          | Sensor-chip-technology |
|                                             |                   |                  |          | Impact on maritime logistics |
|                                             |                   |                  |          | Competitive advantages |
|                                             |                   |                  | Software | Communication technology |
|                                             |                   |                  | Sustainable maritime transport | Energy efficiency |
| De Jong (2017a) [74]                        | *DVZ – Deutsche Verkehrs-Zeitung* | Der Seetransport wird transparenter | Automation | Alarm system |
|                                             |                   |                  |          | Control monitoring |
|                                             |                   |                  | Big Data | Sensor-chip-technology |
|                                             |                   |                  |          | Impact on maritime logistics |
|                                             |                   |                  |          | Reporting |
|                                             |                   |                  | Simulation and modelling | Communication |
|                                             |                   |                  | Sustainable maritime transport | Energy efficiency |
| De Jong (2017b) [75]                        | *DVZ – Deutsche Verkehrs-Zeitung* | Praxisnahes Projekt berechnet Schiffskommutationszeiten in Seehäfen | Big Data | Shiptraffic |
|                                             |                   |                  |          | ETA |
|                                             |                   |                  | Simulation and modelling | VTS |
|                                             |                   |                  | Software | ETA |
|                                             |                   |                  |          | AIS |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Naumann (2016) (76)                         | DVZ – Deutsche Verkehrs-Zeitung | Mehr Effizienz und Sicherheit auf See | Big Data | Networking, Fleet optimization, Shiptraffic, ETA, Simulation and modelling, VTS |
| Naumann and Reimann (2016) (77)            | DVZ – Deutsche Verkehrs-Zeitung | Besser planen dank Bits und Bytes | Automation | Automaatisation in supply chains, Supply chain management, Automaisation in seaports, Big Data, Fleet optimization, Shiptraffic, ETA, Control systems, Software, AIS, Service for port systems |
| De Jong (2016) (78)                         | DVZ – Deutsche Verkehrs-Zeitung | Automatisierung an der Kaikante | Automation | Automaisation in supply chains, Automaisation in seaports, Big Data, Sensor-chip-technology, Impact on maritime logistics, Simulation and modelling, New port facilities, Development, Simulation, Software, AIS, Service for port systems |
| Zapp (2015) (79)                            | DVZ – Deutsche Verkehrs-Zeitung | Technik ersetzt Mannschaft | Automation | Autonomous / smart shipping, Technology development, Big Data, Ship operating, Machine / aggregate, Autonomous / smart shipping, Sustainable maritime transport, Reduction of emissions, Energy efficiency |
| Naumann (2014) (80)                         | DVZ – Deutsche Verkehrs-Zeitung | Die Zukunft gehört dem Smartport | Automation | Automaisation in seaports, Supply chain management, Big Data, Sensor-chip-technology, Impact on maritime logistics, Port administration, Simulation and modelling, New port facilities, Simulation studies, Innovation strategies for future port administrations, Software, Service for port systems |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Naumann (2017b) (81)                        | DVZ – Deutsche Verkehrs-Zeitung | Digitalisierung verändert Schifffahrtsbranche | Automation | Automatisation in supply chains, Digital technology, Supply chain management |
|                                             |                   |                  | Big Data   | Cloud-based eBusiness, Real-time, Cloud-computing |
|                                             |                   |                  | Software   | VOIP |
|                                             |                   |                  |            | Sustainable cost-reduction, Reporting |
| Kloss (2016) (82)                           | DVZ – Deutsche Verkehrs-Zeitung | Und Iris knipst am laufenden Band | Automation | Autonomous / smart shipping, Digital technology |
|                                             |                   |                  | Big Data   | Autonomous / smart shipping |
|                                             |                   |                  | Simulation and modelling | Development in new technologies |
| N.U. (2017) (83)                            | HANSA – International Maritime Journal | Schifffahrt soll mit digitalen Start-ups zusammen arbeiten | Automation | Research and development, Networking, Economic impacts |
|                                             |                   |                  | Big Data   | Economic impacts |
|                                             |                   |                  | Software   | Competitive advantages |
| Selzer (2017a) (84)                         | HANSA – International Maritime Journal | Aufbruch ins Ungewisse | Big Data | Sensor-chip-technology, Impact on maritime logistics, Legislation on competitive advantages |
|                                             |                   |                  | Sustainable Maritime Transport | Governance |
|                                             |                   |                  | Risks | Data misuse, Security of the supply chain, Sabotage |
| Selzer (2017b) (85)                         | HANSA – International Maritime Journal | Autonomy – virtually real? | Automation | Digital technology, Technology development, Production processes |
|                                             |                   |                  | Simulation and modelling | Production processes |
|                                             |                   |                  | Software | |
| Selzer (2017c) (86)                         | HANSA – International Maritime Journal | The human factor in cyber security | Risks | Cyber-attacks, Security of the supply chain |
| Meyer (2017) (87)                           | HANSA – International Maritime Journal | Neue Cyber-Allianz mit bewährter Waffe | Big Data | Reporting, Risk assessment and management |
|                                             |                   |                  | Risks | Data misuse, Cyber-attacks |
| Kuster (2017) (88)                          | HANSA – International Maritime Journal | Intelligent durch ‘smarte’ Verdrahtung | Automation | Digital technology, Control system |
|                                             |                   |                  | Big Data | Control systems |
|                                             |                   |                  | Simulation and modelling | Communication, Production processes |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Leira (2016) (89)                           | HANSA – International Maritime Journal | Neue Ära der Kommunikation auf See | Big Data   | Real-time   |
|                                             |                   |                  |             | Cloud-computing |
|                                             |                   |                  |             | VOIP         |
|                                             |                   |                  |             | Sustainable cost-reduction |
|                                             |                   |                  | Simulation and modelling | Technology development |
|                                             |                   |                  |             | Communication |
|                                             |                   |                  | Software    | Communication technology |
| Selzer (2016) (90)                          | HANSA – International Maritime Journal | Ohne Mann und Maus | Automation | Autonomous / smart shipping |
|                                             |                   |                  |             | Big Data     |
|                                             |                   |                  |             | Autonomous / smart shipping |
|                                             |                   |                  | Software    | AIS          |
|                                              |                   |                  |             | GPS-navigation |
|                                              |                   |                  |             | Routeplanning |
|                                             |                   |                  |             | ETA          |
| Meyer (2016) (91)                           | HANSA – International Maritime Journal | DNV GL will Innovationstreiber sein | Automation | Digital technology |
|                                             |                   |                  |             | Big Data     |
|                                             |                   |                  |             | Control systems |
|                                             |                   |                  | Simulation and modelling | Production processes |
|                                             |                   |                  | Risks       | Cyber-attacks |
| Bertram (2011) (92)                         | HANSA – International Maritime Journal | IT-Trends in Schiffbau und Schifffahrt | Simulation and modelling | Technology development |
|                                             |                   |                  |             | Development   |
|                                             |                   |                  |             | Simulation    |
|                                             |                   |                  |             | Production processes |
|                                             |                   |                  | Software    | Control systems |
|                                             |                   |                  |             | Sustainable Maritime Transport |
|                                             |                   |                  |             | Reduction of emissions |
|                                             |                   |                  |             | Energy efficiency |
| Bertram (2016) (93)                         | HANSA – International Maritime Journal | Smart connected and bigger | Big Data | Sensor-chip-technology |
|                                             |                   |                  |             | Impact on maritime logistics |
|                                             |                   |                  | Simulation and modelling | Optimization simulation |
|                                             |                   |                  | Software    | AIS          |
|                                              |                   |                  |             | GPS-navigation |
|                                              |                   |                  |             | Routeplanning |
|                                              |                   |                  |             | ETA          |
|                                             |                   |                  | Sustainable Maritime Transport | Energy efficiency |
| Bertram (2017) (94)                         | HANSA – International Maritime Journal | Get smart! Autonomy now! | Big Data | Sensor-chip-technology |
|                                             |                   |                  |             | Impact on maritime logistics |
|                                             |                   |                  |             | Internet of Things |
|                                             |                   |                  |             | Virtual reality |
|                                             |                   |                  |             | Autonomous / smart shipping |
|                                             |                   |                  | Simulation and modelling | Optimization simulation |

(Continued)
Table 2. (Continued)

| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|--------------------|-------------------|-------------|-------------|
| Bertram (2015) [95]                         | HANSA – International Maritime Journal | IT for smarter ship design and operation | Big Data | Shiptraffic |
|                                             |                     |                   |             | ETA         |
|                                             |                     |                   |             | Virtual reality |
|                                             |                     | Simulation and modelling | VTS |             |
|                                             |                     | Software | AIS |             |
|                                             |                     |                  | GPS-navigation |             |
|                                             |                     |                  | Routeplanning |             |
|                                             |                     |                  | ETA |             |
| Hochhaus (2011) [96]                        | HANSA – International Maritime Journal | IT-Lösungen für die Schifffahrt | Big Data | Control systems |
|                                             |                     |                   |             | Augmented reality |
|                                             |                     | Software | AIS |             |
|                                             |                     |                  | GPS-navigation |             |
|                                             |                     |                  | Routeplanning |             |
|                                             |                     |                  | ETA |             |
|                                             |                     | Simulation and research |             |             |
| Doyle (2017) [97]                           | Maritime Logistics Professional | Cyber attacks threaten shipping & dominate maritime news | Risks | Cyber-attacks |
| Keefe (2017) [98]                           | Maritime Logistics Professional | Cloud-based global trade Management: The sky is the limit | Automation | Cloud-based eBusiness |
| Keefe (2016) [99]                           | Maritime Logistics Professional | Cyber security: Wake up call | Risks | Cyber-attacks |
| Keefe (2014) [100]                          | Maritime Logistics Professional | Optimize performance via data analytics | Big Data | Sensor-chip-technology |
|                                             |                     |                  |             | Impact on maritime logistics |
|                                             |                     |                  |             | Competitive advantages |
|                                             | Sustainable Maritime Transport | Sustainable maritime transport |             | Energy efficiency |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title                                                                 | Major topic                | Subtopic(s)                                           |
|---------------------------------------------|-------------------|-----------------------------------------------------------------------------------|---------------------------|-------------------------------------------------------|
| Muccin (2015) (101)                         | Maritime Reporter and Engineering News | Combatting maritime cyber security threats                                         | Automation                | Autonomous / smart shipping                           |
|                                             |                   |                                                                                   | Big Data                  | Autonomous / smart shipping                           |
|                                             |                   |                                                                                   | Ship operating            |                                                       |
|                                             |                   |                                                                                   | Machine / aggregate      |                                                       |
|                                             |                   |                                                                                   | Simulation and modelling  | Technology development                                 |
|                                             |                   |                                                                                   | Optimization              |                                                       |
|                                             |                   |                                                                                   | Simulation                |                                                       |
|                                             |                   |                                                                                   | Software                 | AIS                                                   |
|                                             |                   |                                                                                   |                           | GPS-navigation                                        |
|                                             |                   |                                                                                   |                           | Routeplanning                                         |
|                                             |                   |                                                                                   |                           | ETA                                                  |
|                                             |                   |                                                                                   |                           | Communication technology                              |
|                                             |                   |                                                                                   | Risks                     | Data misuse                                           |
|                                             |                   |                                                                                   |                           | Cyber attacks                                         |
| Trauthwein (2017a) (102)                    | Maritime Reporter and Engineering News | Rolls-Royce blue ocean team looks to the future                                    | Automation                | Automatisation in supply chains                       |
|                                             |                   |                                                                                   | Autonomous / smart shipping|                                                       |
|                                             |                   |                                                                                   | Supply chain management   |                                                       |
|                                             |                   |                                                                                   | Sustainable Maritime Transport| Energy efficiency                                    |
| Trauthwein (2017b) (103)                    | Maritime Reporter and Engineering News | Software solutions: Monitor & Track                                               | Big Data                  | Sensor-chip-technology                                |
|                                             |                   |                                                                                   |                           | Impact on maritime logistics                         |
|                                             |                   |                                                                                   |                           | Real-time                                             |
|                                             |                   |                                                                                   |                           | Cloud-computing                                      |
|                                             |                   |                                                                                   |                           | VOIP                                                  |
|                                             |                   |                                                                                   |                           | Sustainable cost-reduction                            |
|                                             |                   |                                                                                   |                           | Economic impacts                                      |
|                                             |                   |                                                                                   | Simulation and modelling  | Technology development                                 |
|                                             |                   |                                                                                   |                           | Simulation                                            |
|                                             |                   |                                                                                   |                           | Optimization                                          |
|                                             |                   |                                                                                   | Software                 | AIS                                                   |
|                                             |                   |                                                                                   |                           | GPS-navigation                                        |
|                                             |                   |                                                                                   |                           | Routeplanning                                         |
|                                             |                   |                                                                                   |                           | ETA                                                  |
|                                             |                   |                                                                                   |                           | Communication technology                              |
|                                             |                   |                                                                                   |                           | Sustainable transport models                         |
| Bobys (2017) (104)                          | Maritime Reporter and Engineering News | A case for maritime cyber security capability                                     | Risks                     | Data misuse                                           |
|                                             |                   |                                                                                   |                           | Cyber-attacks                                         |
| Berge (2017) (105)                          | Maritime Reporter and Engineering News | Maritime cyber security: Good, better & best                                       | Big Data                  | Networking                                            |
|                                             |                   |                                                                                   | Risks                     | Data misuse                                           |
|                                             |                   |                                                                                   |                           | Cyber-attacks                                         |
|                                             |                   |                                                                                   |                           | Research on the risks of security of the supply chain |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Gruca (2017) (106)                          | Maritime Reporter and Engineering News | Industry 4.0 on the high seas | Big Data | Sensor-chip-technology, Impact on maritime logistics, Real-time, Cloud-computing, VOIP, Sustainable cost-reduction, Research to reduce emissions, Sustainable Maritime Transport, Reduction of emissions, Energy efficiency |
| Pekkanen (2017) (107)                       | Maritime Reporter and Engineering News | Big Data & a level playing field | Big Data | Fleet optimization, Sensor-chip-technology, Impact on maritime logistics, Real-time, Cloud-computing, VOIP, Sustainable cost-reduction, Shiptraffic, ETA, Software, AIS, GPS-navigation, Routeplanning, ETA, Cargodata, Control systems, Communication technology, Sustainable Maritime Transport, Energy efficiency |
| Pribyl (2016) (108)                         | Maritime Reporter and Engineering News | Drones: Is the maritime industry ready? | Automation | Automatisation in seaports, Research and development, Technology development, Control system, Big Data, Competitive advantages, Economic impacts, Cost-benefit analysis, Legislation on competitive advantages, Infrastructure, Risks, Security of the supply chain |

(Continued)
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Segercrantz (2016a) (109)                   | Maritime Reporter and Engineering News | Cyber security in shipping & offshore ops | Big Data | Control systems |
|                                             |                    |                  |             | Transactional data |
|                                             |                    |                  | Simulation and modelling | Communication |
|                                             |                    |                  | Risks | Cyber-attacks |
|                                             |                    |                  |           | Sabotage |
|                                             |                    |                  |           | Security of the supply chain |
| Muccin (2016) (110)                         | Maritime Reporter and Engineering News | Cyber world: Safer seas via phantom ships | Automation | Autonomous / smart shipping |
|                                             |                    |                  | Big Data | Sensor-chip-technology |
|                                             |                    |                  |           | Impact on maritime logistics |
|                                             |                    |                  |           | Control systems |
|                                             |                    |                  |           | Autonomous / smart shipping |
|                                             |                    |                  | Software | AIS |
|                                             |                    |                  |           | GPS-navigation |
|                                             |                    |                  |           | Routeplanning |
|                                             |                    |                  |           | ETA |
|                                             |                    |                  |           | Control systems |
|                                             |                    |                  | Risks | Cyber-attacks |
|                                             |                    |                  |           | Social risks (loss of workplaces) |
|                                             |                    |                  |           | Research on the risks of security of the supply chain |
| Stoichevski (2016) (111)                    | Maritime Reporter and Engineering News | The ‘paperless’ ship | Automation | Cloud-based eBusiness |
|                                             |                    |                  | Big Data | Digital technology |
|                                             |                    |                  |           | Technology development |
|                                             |                    |                  |           | Autonomous / smart shipping |
|                                             |                    |                  | Big Data | Real-time |
|                                             |                    |                  |           | Cloud-computing |
|                                             |                    |                  |           | VOIP |
|                                             |                    |                  |           | Sustainable cost-reduction |
|                                             |                    |                  |           | Cloud-based eBusiness |
|                                             |                    |                  |           | VOIP |
|                                             |                    |                  |           | Autonomous / smart shipping |
|                                             |                    |                  | Simulation and modelling | Technology development |
|                                             |                    |                  |           | Communication |
|                                             |                    |                  |           | Development in new technologies |
|                                             |                    |                  |           | Technologies to transform aims |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Haun (2015) [112]                           | Maritime Reporter and Engineering News | E-Procurement streamlined via the cloud | Automation | Cloud-based eBusiness, Digital technology |
|                                             |                   |                  | Big Data    | Real-time, Cloud-computing, VOIP, Sustainable cost-reduction, Cloud-based eBusiness, Reporting, Web services |
|                                             |                   |                  | Simulation and modelling | Optimization, Simulation, Development in new technologies |
| Segercrantz (2016b) [113]                   | Maritime Reporter and Engineering News | Big Data & big savings for maritime ops | Automation | Automatisation in supply chains, Cloud-based eBusiness, Digital technology, Technology development |
|                                             |                   |                  | Big Data    | Sensor-chip-technology, Impact on maritime logistics, Real-time, Cloud-computing, VOIP, Sustainable cost-reduction, Cloud-based eBusiness, Control systems, Web services |
|                                             |                   |                  | Simulation and modelling | Technology development, Communication, Development in new technologies |
| Hartmann and Remick (2015) [114]            | Maritime Reporter and Engineering News | Cyber security & the challenge to maritime networks | Big Data | Networking |
|                                             |                   |                  | Simulation and modelling | Communication, Technologies to transform aims |
|                                             |                   |                  | Software | Communication technology |
|                                             |                   |                  | Risks    | Cyber-attacks |
| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|-------------------|-------------|-------------|
| Rhodes and Soccoli (2015) [115]             | Maritime Reporter and Engineering News | Big Data: Big value or big risk? | Big Data | Transform aims, Internet of things, VOIP, Software, AIS, GPS-navigation, Routeplanning, ETA, Control systems, Communication technology, Risks, Cyber-attacks, Terrorist attacks |
| Segercrantz (2015a) [116]                   | Maritime Reporter and Engineering News | DNV GL: ‘Big Data’ evolving fast; LNG slower than expected | Big Data | Internet of things, Research to reduce emissions, Implementing green supply chain practices, Simulation and modelling, Technology development, Development in new technologies, Sustainable Maritime Transport, Reduction of emissions, Energy efficiency, Green shipbuilding industry |
| Weigel and Singleton (2014) [117]          | Maritime Reporter and Engineering News | Electronic navigation & dispute resolution: Coming of age | Simulation and modelling | Development in new technologies, Software, AIS, GPS-navigation, Routeplanning, ETA, Control systems, Simulation and research |
| Bryant (2017) [118]                        | Maritime Reporter and Engineering News | Balancing efficiency & security as maritime goes digital | Simulation and modelling | Development in new technologies, Software, AIS, GPS-navigation, Routeplanning, ETA, Control systems, Sustainable Maritime Transport, Energy efficiency, Risks, Cyber-attacks |
| Author, year of publication, reference number | Publication outlet                          | Publication title                                               | Major topic                  | Subtopic(s)                                                                 |
|---------------------------------------------|--------------------------------------------|----------------------------------------------------------------|-----------------------------|----------------------------------------------------------------------------|
| Haynes (2016) (119)                         | Maritime Reporter and Engineering News     | Unmanned surface vessels: From concept to service                | Automation                  | Autonomous / smart shipping                                                |
|                                             |                                            |                                                                  | Autonoma / smart shipping   | Control systems                                                            |
|                                             |                                            |                                                                  | Research to reduce emissions|                                                                            |
|                                             |                                            |                                                                  | Simulation and modelling    |                                                                            |
|                                             |                                            |                                                                  | Production processes        |                                                                            |
|                                             |                                            |                                                                  | Technologies to transform aims |                                                                            |
|                                             |                                            |                                                                  | Simulation studies          |                                                                            |
|                                             |                                            |                                                                  | Sustainable Maritime Transport |                                                                            |
|                                             |                                            |                                                                  | Energy efficiency           |                                                                            |
| Stoichevski (2015) (120)                    | Maritime Reporter and Engineering News     | The maritime launch of Big Data                                 | Big Data                    | Networking                                                                 |
|                                             |                                            |                                                                  | Sensor-chip-technology      |                                                                            |
|                                             |                                            |                                                                  | Impact on maritime logistics|                                                                            |
|                                             |                                            |                                                                  | Reporting                   |                                                                            |
|                                             |                                            |                                                                  | VOIP                        |                                                                            |
|                                             |                                            |                                                                  | Simulation and modelling    |                                                                            |
|                                             |                                            |                                                                  | Technology development      |                                                                            |
|                                             |                                            |                                                                  | Communication               |                                                                            |
| Driver (2015) (121)                         | Maritime Reporter and Engineering News     | Big IT: How fast, how far will IT drive maritime?                | Big Data                    | Networking                                                                 |
|                                             |                                            |                                                                  | Real-time                   |                                                                            |
|                                             |                                            |                                                                  | Cloud-computing             |                                                                            |
|                                             |                                            |                                                                  | VOIP                        |                                                                            |
|                                             |                                            |                                                                  | Sustainable cost-reduction  |                                                                            |
|                                             |                                            |                                                                  | Internet of things          |                                                                            |
|                                             |                                            |                                                                  | Research to reduce emissions|                                                                            |
|                                             |                                            |                                                                  | Port administration         |                                                                            |
|                                             |                                            |                                                                  | Competitive advantages      |                                                                            |
|                                             |                                            |                                                                  | Simulation and modelling    |                                                                            |
|                                             |                                            |                                                                  | Development in new technologies-Simulation                     |                                                                            |
| Segercrantz (2015b)                         | Maritime Reporter and Engineering News     | Unmanned vessel: The future is now                              | Automation                  | Control system                                                             |
|                                             |                                            |                                                                  | Autonomous / smart shipping |                                                                            |
|                                             |                                            |                                                                  | Sensor-chip-technology      |                                                                            |
|                                             |                                            |                                                                  | Impact on maritime logistics|                                                                            |
|                                             |                                            |                                                                  | Fleet optimization          |                                                                            |
|                                             |                                            |                                                                  | Sustainable Maritime Transport |                                                                            |
|                                             |                                            |                                                                  | Energy efficiency           |                                                                            |
|                                             |                                            |                                                                  | Risks                       |                                                                            |
|                                             |                                            |                                                                  | Cyber-attacks               |                                                                            |
|                                             |                                            |                                                                  | Security of the supply chain|                                                                            |
| Baldauf (2013) (122)                        | Maritime Reporter and Engineering News     | Standardization for safer shipping of e-navigation & training    | Software                    | AIS                          |
|                                             |                                            |                                                                  | GPS-navigation              |                                                                            |
|                                             |                                            |                                                                  | Routeplanning               |                                                                            |
|                                             |                                            |                                                                  | ETA                         |                                                                            |
|                                             |                                            |                                                                  | Control systems             |                                                                            |
|                                             |                                            |                                                                  | Communication technology    |                                                                            |
|                                             |                                            |                                                                  | Simulation and research     |                                                                            |
Table 2. (Continued)

| Author, year of publication, reference number | Publication outlet | Publication title | Major topic | Subtopic(s) |
|---------------------------------------------|-------------------|------------------|-------------|-------------|
| Trauthwein (2013) [124]                     | Maritime Reporter and Engineering News | Software solutions picking up steam | Big Data | Fleet optimization |
|                                             |                    |                   |             | Real-time    |
|                                             |                    |                   |             | Cloud-computing |
|                                             |                    |                   |             | VOIP         |
|                                             |                    |                   | Simulation and modelling | Technology development |
|                                             |                    |                   |             | Development in new technologies |
|                                             |                    |                   |             | Simulation studies |
|                                             |                    |                   | Software | Control systems |
|                                             |                    |                   |             | Communication technology |
|                                             |                    |                   |             | Sustainable transport models |
|                                             |                    |                   |             | AIS           |
|                                             |                    |                   |             | GPS-navigation |
|                                             |                    |                   |             | Routeplanning |
|                                             |                    |                   |             | ETA           |
|                                             |                    |                   | Sustainable maritime transport | Energy efficiency |

4. Analysis

4.1. Results
The results of the literature analysis are depicted in the concept matrix in Table 3.

In the following, we assigned the publications to subject-specific clusters and analyzed them accordingly. Before explaining the defined clusters in more detail, it must be pointed out that the individual contributions do not always allow for a clear assignment, since they often refer to aspects of different clusters. Therefore, the respective thematic main focus of each contribution was decisive for its clustering.

In the practical as well as the scientific literature of the years 2003 through 2017, a total of 124 relevant contributions covering the topic of digitization in maritime logistics were identified. The publications cover a broad spectrum and show the areas in need of development. It is striking that in the analyzed literature there is no systematic literature review on digitization in maritime logistics and it must be assumed that no literature review has been carried out on this topic until now. The majority of the identified contributions (88%) stems from IS-, maritime- and management-related journals or conferences, the remaining contributions (12%) are book publications. Furthermore, 22% of the articles originate from the general transport and logistics sector, 33% are IS or management-related articles and almost half of the identified contributions (45%) stem from the maritime logistics sector. Almost all publications are written in English (98%), which is related to the fact that the keyword search in the search engines of the literature databases and trade journals was carried out in English. In addition to the search in the literature, we carried out an open Google search (forward and backward) by applying all keyword combinations. In comparison to the scientific contributions, all 72 practical contributions were published in maritime- and transport-related journals. Of these, 39 contributions (54%) were written in German, the remaining 33 contributions (46%) in English.

Furthermore, we looked at the countries of origin of the respective leading authors in the scientific literature, or rather their institutions. As to the scientific literature, there is a strong concentration of
Table 3. Stakeholders and artifacts in scope of digitization in maritime logistics

| Who? | Logistics providers | Infrastructure and service providers | Maritime industries | Research and scientific community | Governments |
|------|---------------------|-------------------------------------|---------------------|----------------------------------|-------------|
|      | Example Reference   | Example Reference                   | Example Reference   | Example Reference                | Example Reference |
| Automation | Control monitoring | Cloud-based eBusiness (2), (8), (7), (11), (24), (55), (56), (68), (74), (75), (111), (113), (115) | Digital Technology (1), (13), (56), (81), (82), (85), (89), (110), (113), (115), (117) | Research and development (15), (23), (45), (47), (71), (72), (81), (83), (88) | Energy optimization (9), (15), (25), (58), (86), (122) |
| Alarm system | Automation in seaports | (2), (8), (12), (23), (63), (77), (80), (83) | Control system | (27), (62), (65), (88), (108), (122) | Technology development (41), (79), (85), (122), (123) |
|      | Supply chain management | (71) | | | Community Stakeholders (1) |
|      |                      | | | | Infrastruc (19) |
| Big Data | Ship operating, Machine/ Aggregate | (24), (59), (63), (79) | Cloud-based eBusiness | (24), (28), (59), (62), (83), (85), (113), (115), (117) | Transform aims | (11), (115) |
|      |                      | | | | Optimization of administrative procedures (51), (88) |
|      |                      | | | | | Air quality, Atmospheric environment (12), (24), (40), (54) |
|      |                      | | | | | Legislation on competitive advantages (23), (33), (34), (37), (45), (54), (56) |
|      |                      | | | | | Transactional data (43), (120) |
|      |                      | | | | | | |
|      | Networking | (35), (40), (50), (56), (66), (70), (73), (77), (78), (80), (90), (103), (105), (122), (124) | VOIP | (38), (55), (67), (85), (113), (115), (117) | Implementing green supply chain practices (42), (138) |
|      |                      | | | | | Web services | (50), (82), (112), (122) |
|      |                      | | | | | | Infrastructure | (120), (403), (714) |
|      | Sensor-chip-technology, impact on maritime logistics | (8), (25), (56), (59), (61), (67), (70), (78), (80), (84), (95), (99), (103), (105), (107), (109), (113), (126), (122) | Shiptraffic, ETA | (19), (38), (46), (55), (73), (75), (77), (79), (85), (113), (117), (121) | Internet of Things (IoT) | (94), (115), (123) |
|      |                      | | | | | | Cost-benefit analysis | (31), (108) |
|      |                      | | | | | | | Virtual Reality (VR) | (94), (95) |
|      |    Real-time, cloud-computing, VOIP, sustainable cost-reduction | (58), (59), (67), (70), (73), (78), (80), (84), (95), (99), (103), (105), (107), (110), (113), (121), (124) | Port administration | (44), (62), (83), (85), (121) | Augmented Reality (AR) | (96) |
|      |                      | | | | | | | | | |
|      | Risk assessment and management | (46), (60), (87) | Economic impacts | (95), (96), (97), (110), (120) | Autonomous / smart shipping | (80), (85), (79), (72), (79), (82), (90), (101), (102), (108), (112), (119), (122) |
|      |                      | | | | | | | | | |
|      | Simulation and modelling | (12), (45), (62), (63), (67), (81), (101), (103), (111), (118), (130), (132) | Development, Simulation | (46), (47), (48), (49), (51), (57), (58), (72), (80), (101), (112) | Production processes | (51), (85), (86), (88), (89), (92), (113) |
|      |                      | | | | | | | | | Simulation studies | (23), (38), (44), (115), (116), (119), (120) |
|      | New port facilities | (33), (40), (47), (78), (80) | Administration | (45), (60), (88) | Technologies to transform aims | (11), (115), (117), (118) |
|      |                      | | | | | | | | | Development in new technologies | (48), (58), (77), (78), (91), (101), (112), (113), (117), (130), (132), (134) |
|      | Software | AIS, GPS-Navigation, routeplanning, ETA | (23), (24), (30), (35), (36), (38), (46), (51), (52), (55), (70), (80), (90), (95), (96), (101), (107), (108), (115), (117), (118), (123), (126) | Control systems | (25), (29), (38), (40), (50), (89), (109), (115), (117), (118), (123), (124) | Simulation and research | (11), (44), (46), (47), (55), (57), (61), (63), (134) |
|      |                      | | | | | | | | | | Sustainable transport models | (7), (21), (35), (37), (39), (58), (73), (77), (78), (81), (101), (107), (113), (114), (115), (123), (124) |

(Continued)
authors from the EU (55%), followed by authors from Asia (31%), North America, and Australia (6%) as well as Egypt (2%). Considering the identified practical contributions, the share of authors from the EU is similarly high (62%). The remaining articles originate from North America (38%).

Given the fact that artifacts such as big data, simulation and modeling and sustainable maritime transport play an important part in the digitization of maritime logistics, and thus are equally essential for all involved stakeholders, it is comprehensible that many of the identified contributions address such artifacts as well as the corresponding ICT. It is, however, surprising that only few publications stem from the maritime industry (i.e. shipbuilding and offshore industry). From the above results, it is clear that within the scientific community the research field digitization of maritime logistics is still in its initial stage. In practice literature, the situation is different as can be seen from the following contributions: The optimization of processes in the maritime logistics chain by new technologies and the resulting reduction of costs (Lüders, 2016), the transparency of the sea transport by sensor chip technologies (De Jong, 2017a) and the autonomous navigation and the subsequent reduction in ship occupancies (Selzer, 2016) are often discussed topics. Nevertheless, the analyzed publications show a clear homogeneity regarding the benefits of digitization for maritime logistics.
Table 4. PESTEL-Matrix with recommendations for digitization in maritime logistics

| Challenge 1: | Compliance with future stricter environmental requirements: |
|-------------|----------------------------------------------------------|
| The maritime logistics chain will change as a result of increasingly stringent environmental directives. The environmental directives limit the sulfur content of bunker oil at 3.5% from January 2020 to 0.5% (Gilbert, 2014). Since 2015, 0.1% has already been applied to areas which are particularly protected. A climate friendly and forward-looking fuel is, among other things, liquid natural gas (LNG), in its use in the long term hardly anyone will pass by (Brandt, 2016). However, when a shipping company converts to low-emission engines is an individual decision. CO2 emissions and noise can be avoided in the ports by feeding eco-friendly electricity from ashore side into the onboard network. |

| Challenge 2: | Digital transformation of the maritime logistics chain + Data security and data protection |
|-------------|--------------------------------------------------------------------------------------|
| Digitization will change maritime logistics through intelligent networking of logistical processes and automation, and will contribute to increasing efficiency in shipping, management and service (Brouer et al., 2016), in which business models and their processes will be changing significantly in the foreseeable future: |
| - Real-time tracking of cargo and cloud-based monitoring of ship systems are no longer a future issue (Biccario et al., 2014). |
| - The remote controlled or fully automatic ship operation will become reality in the foreseeable future (Maluck, 2016). |
| - Digital players will enter the market as competitors and support the digital conversion of maritime logistics with technical solutions (Brandt, 2016). |
| The stakeholders of maritime logistics should adapt themselves to new competitors, invest in digital business models and in the future assume more tasks in the maritime supply chain in order to remain viable. Digitization will force shipping companies to deepen their service portfolios and cover the entire supply chain, not just at sea but also increasingly on land (Brandt, 2016). |
| The growing volume of data, the demand for mobility in logistics and the exchange of information also lead to a growing need for data security and data protection in maritime logistics in order to prevent manipulations of sensitive systems. Existing defensive concepts (defense-in-depth models) are increasingly reaching their limits. Companies should protect their data against unauthorized access and any kind of abuse by cloud-based user systems, access management, device management and data backup, and make appropriate investments in IT security. |

| Challenge 3: | Big Data in maritime logistics + Process optimization |
|-------------|------------------------------------------------------|
| The use of Big Data holds potentials and risks at the same time: |
| - Operational planning and control processes can be improved in the maritime supply chain (Brouer et al., 2016). |
| - Based on mathematical algorithms, based on real-time data from ship operation, ship arrival times can be predicted earlier and more accurately. In the future the stakeholders involved in the maritime logistics chain will be able to adjust their resource dispositions flexibly in an early stage to adapt to the ships arrival time. |
| The significant volume growth in the area of container traffic, as well as other maritime transport services, poses major challenges for the logistics chain. The actors of the maritime logistics chain should present and model the existing processes in a process optimization software and then optimize them. In addition to the development of meta-simulation models, for example for container terminals in the seaports, with a discreet, event-oriented character, optimization methods from other economic sectors could also be taken into account and these would then be made use of for maritime logistics. Examples of Lean Management, from the further development of the term Lean Production, should be mentioned here. This creates opportunities for improving the quality of the maritime supply chain as well as increasing productivity and optimizing the process as a whole. Ship arrival times can be optimized and more accurately predicted, using new technologies as well as reduced waiting times in ports (Fruth, 2016). Equipped with RFID technologies, the path of a product can be tracked and monitored in a container, from the consignor to the consignee, without any gaps (Bai et al., 2010). The goods are cross linked across borders. Operating conditions and coordinates of goods can be interchanged and communicated. |

(Continued)
Challenge 4: Financial support: Political

For years sea shipping has been in one of its most severe crises. There is no fresh capital to modernize fleets or to implement other large scale projects, because for many banks an engagement in shipping is no longer an option. In difficult times like these, many maritime companies hesitate to invest in new technologies due to high investment costs. One of the most important challenges is to motivate and promote maritime companies for the introduction of new technologies, for example through financial support measures by the Federal Ministry of Transport and Digital Infrastructure (BMVI) and through government sponsored funding programs for the maritime economy and research.

Challenge 5: Regulatory compliance: Legal

The use of the AIS (Automatic Identification System) and RFID technologies requires the automated recording of personal data in some applications. When using the AIS technology, ships have a transponder on board, identify themselves among themselves, as well as with traffic control centers on land, and make relevant static, travel related and dynamic data clearly known. Personal data of the watchkeeping officer or captain are also transmitted. In these cases there are ethical and legal concerns regarding the privacy of the respective crew members. These data are available for everyone who has a corresponding receiver and can therefore pose a threat to the ship and its crew members when the ship is, for example in driving areas, affected by pirates or other criminal acts. Prior to the implementation of these technologies, restrictions on privacy and data protection should be reviewed by legislation.

In addition reliable and political framework conditions, especially in the course of digitization and automation in the maritime logistics chain, are recommended so that seaports can continue to function as logistical hubs. Regulatory guidelines, on the part of the governments, could make the economic development of port cities and entire coastal regions more difficult. Uniform conditions of competition, as well as an environmental policy that would allow for future development opportunities for seaports, would be a possible approach.

Challenge 6: Social impact of digitization on the qualification and competencies of specialists in maritime logistics: Social

Through the digitization and automation of many areas maritime logistics will change. Smart-Shipping will create more attractive and responsible jobs onshore for the monitoring and remote maintenance of ships (Binder, 2016c). However, the use of new technologies requires appropriate expertise and the need for advanced skills. An increasing need for training and development in the field of new technologies will be necessary in the future. The major challenge is therefore to create and develop new competencies, to optimize project organizations and to gain new talents. Experience, willingness to integrate and technical knowledge are among the most important issues that should be considered. Companies should work with their employees to develop ideas, for example on the basis of “planning games”, how they can implement these things and introduce ideas for the creation of innovations. This enables effective analysis of business processes as well as the disclosure of existing improvement potentials by realizing company processes. Furthermore, interdisciplinary groups could be formed to work together to increase the efficiency of the companies.

Table 4. (Continued)

| Digitization in maritime logistics: | Perspective |
|-----------------------------------|-------------|
| Recommendations for action:       | PESTEL      |
| Challenge 4:                      | Financial support: Political |
| For years sea shipping has been in one of its most severe crises. There is no fresh capital to modernize fleets or to implement other large scale projects, because for many banks an engagement in shipping is no longer an option. In difficult times like these, many maritime companies hesitate to invest in new technologies due to high investment costs. One of the most important challenges is to motivate and promote maritime companies for the introduction of new technologies, for example through financial support measures by the Federal Ministry of Transport and Digital Infrastructure (BMVI) and through government sponsored funding programs for the maritime economy and research. |
| Challenge 5:                      | Regulatory compliance: Legal |
| The use of the AIS (Automatic Identification System) and RFID technologies requires the automated recording of personal data in some applications. When using the AIS technology, ships have a transponder on board, identify themselves among themselves, as well as with traffic control centers on land, and make relevant static, travel related and dynamic data clearly known. Personal data of the watchkeeping officer or captain are also transmitted. In these cases there are ethical and legal concerns regarding the privacy of the respective crew members. These data are available for everyone who has a corresponding receiver and can therefore pose a threat to the ship and its crew members when the ship is, for example in driving areas, affected by pirates or other criminal acts. Prior to the implementation of these technologies, restrictions on privacy and data protection should be reviewed by legislation. |
| Challenge 6:                      | Social impact of digitization on the qualification and competencies of specialists in maritime logistics: Social |
| Through the digitization and automation of many areas maritime logistics will change. Smart-Shipping will create more attractive and responsible jobs onshore for the monitoring and remote maintenance of ships (Binder, 2016c). However, the use of new technologies requires appropriate expertise and the need for advanced skills. An increasing need for training and development in the field of new technologies will be necessary in the future. The major challenge is therefore to create and develop new competencies, to optimize project organizations and to gain new talents. Experience, willingness to integrate and technical knowledge are among the most important issues that should be considered. Companies should work with their employees to develop ideas, for example on the basis of “planning games”, how they can implement these things and introduce ideas for the creation of innovations. This enables effective analysis of business processes as well as the disclosure of existing improvement potentials by realizing company processes. Furthermore, interdisciplinary groups could be formed to work together to increase the efficiency of the companies. |

Table 4. (Continued)
In the area of new technologies and Big Data Analytics, the authors analyzed an efficiency increase in the area of ship operations, as well as an optimization of the maritime traffic through the exchange of data between ship–ship and ship–land actors and the use of ICT (Haraldson, 2015; Roumboutsos, Nikitakos, & Gritzalis, 2005). Port Community Systems (Carlan, Sys, & Vanelslander, 2016) and e-transformation systems based on IT transform and enhance the internal and external value chains as well as the transshipment activities in the ports (Lee et al., 2016). The smart, RFID-equipped container contributes to the sustainability of sea transport and significantly improves the transparency and security of international intermodal container traffic (Haraldson, 2015). In addition, RFID technologies enable the involved stakeholders to ensure a complete transparency along the entire process chain (Prokop, 2012).

Based on the AIS technology, real-time monitoring can be used to prevent pollution and protect the environment, as AIS technology optimizes maritime traffic, reduces the risk of accidents and minimizes environmental pollution (Yao Yu & ChangChuan, 2011). The fact that sustainability in the field of sea transport is a central and forward-looking theme, the actors of the entire maritime logistics chain are faced with corresponding challenges (Psaraftis, 2016; Stevens, Sys, Vanelslander, & van Hassel, 2015). The topic of cyberattacks and data misuse is also given much consideration in practical literature (Segercrantz, 2016a), as there is consensus that digitization is supposed to improve cybersecurity (Binder, 2016a) and needs a legal framework (Fabarius, 2017c).

As in other areas of the economic world, the analyzed literature shows that digitalization does not only bear chances but also risks, such as data misuse, cyberattacks as well as the loss of certain jobs for the maritime industry (Bendel, 2015; Sen, 2016), which must also be considered.

4.2. Discussion
The results indicate that research in the digitization of maritime logistics is still in its initial stages. Our wide-ranging search revealed only a small number of scientific literature and shows that digitalization in the maritime logistics chain is currently being addressed and considered rather than practical scientific literature. With regard to our research questions, we come to the following conclusion: Digitization has already reached in maritime logistics in some areas and its potential to change the maritime industry is huge. Automation and digitalization are progressing and have changed processes in ship operation and in port handling. Smart container technologies (RFID) and real-time tracking of cargo, for example, increase the transparency on the transport route from the sender to the recipient. Shipping companies are already in a position to operate their own tracking apps in the near future, where the location of the container can be determined by means of a GPS signal (Brandt, 2017). By using modern sensor chip technologies, a large number of data are already recorded at sea and analyzed onshore, which allows the optimization of process flows on board as well as in the handling in ports. Further, it reduces waiting times and costs (De Jong, 2016). The focus of the identified papers is on the optimization of ship operation and terminal transshipment procedures by means of GPS, ICT as well as closely networked stakeholders. However, the areas of sustainability, emissions reduction, use of alternative fuels, as well as the risks of cyberattacks find little consideration in the identified literature. A growing volume of data in the area of the optimization of maritime traffic, port handling operations, and smart container technologies (e.g. RFID and sensor technologies) is expected.

Digital technologies will ensure shorter waiting times for ships and faster processing at the terminal. Besides, ship crews will be able to adapt their navigation using real-time updates to weather, wind, and ocean currents, which involves reduced energy consumptions (Lee et al., 2016). In view of the MARPOL guidelines on climate protection and stricter environmental requirements, the shipping companies will have to equip their fleets with more environmentally friendly marine propulsion systems in order to be able to use alternative fuels such as liquefied petroleum gas (LNG) in the future (Brandt, 2016). Although the emissions in ports are already being slightly reduced by the use of marine diesel instead of heavy oil, CO₂, nitrogen oxides, particulate matter and sulfur oxides are the main sources of the environmental pollution. To reduce such pollution, electric energy could be fed
into the ship’s network from onshore, which would require appropriate connections and converters (Winkel, Weddige, Johnsen, Hoen, & Papaefthimiou, 2016). Thanks to the digitization, it is further already technically possible to monitor the system ship from a central station onshore. In the future, the technical know-how will be needed rather onshore than on board of the ships (Binder, 2016c).

The digitalization in the maritime logistics sector offers a multitude of opportunities and challenges. For example, companies could take advantage of the digital transformation and position themselves on the market with applicable products, services or innovative business models (Brandt, 2017). On the whole, one can safely assume that there will be fundamental changes in ship operation and ICT. The shipping companies are assuming that, as a result of digitization, companies such as Google and Amazon will support the digital conversion of the shipping industry through technical services and will have to confront an increasing number of new competitors. Given this dramatically changing performance spectrum, also the shipping companies are forced to increasingly assume new tasks in order to remain competitive (Brandt, 2016).

As in aviation, the unmanned operation of ships is also feasible in maritime shipping. Experts predict the use of autonomous feeder ships that will transport containers on particular routes with limited reach. However, their opinions diverge as to when the first unmanned seagoing vessel will travel over the world’s sea. On the industry side, it is assumed that the first autonomous ship will become a reality at the end of this decade (Maluck, 2016). According to the IT industry, however, it will still take 15 to 20 years (Kuchta, 2016). Given the high complexity of variables, many of them being unknown or difficult to predict (e.g. tide, weather, terrorism, emergency situations, increasing ship traffic), it is rather unlikely that large seagoing vessels can entirely be operated without staff (Berg & Hauer, 2015). And yet, the electronic on-board systems are in a position to take over a large part of the tasks and provide support so that the crew sizes will be further reduced (Burmeister, Bruhn, Rødseth, & Porathe, 2014).

As any networked data system, ships are also an attractive target for hacker attacks. The real-time data transmission of the smart, RFID-equipped container renders transparent the container’s position, its content, and the state of goods at all times. Likewise, it can be traced whether the container was opened illegally or not. This transparency can indeed conceal immense dangers, such as criminal cyberattacks or unintentional data leaks (Berg & Hauer, 2015). The digital navigation systems of the ships could be manipulated so that they sheer off or run aground. Also a single power failure can have far-reaching consequences in a networked and digital environment (Kuchta, 2016). In maritime logistics, a large number of mostly international stakeholders are involved in transport processes. The increase in digitization and networking between ships, shipping companies, port companies, offshore installations, authorities and other communication partners onshore increase the risk of cyberattacks for all stakeholders involved. Therefore, all players in the maritime supply chain will have to ensure the best possible protection in order to ward off cyberattacks, which has to be ensured by consequently investing in the future development as well as expansion of IT security systems (Segercrantz, 2016a).

Due to the resulting logistics processes, the information requirements and the requirements for the logistical planning and control processes are high. As a result, protected and effective ICT gain in importance in maritime logistics as they contribute to increasing safety and effectiveness in maritime transport and port management (Jahn, Bosse, & Schwientek, 2011). The results of the literature analysis indicate that the digitization of maritime logistics is still at the beginning of its development. So far, only sub areas have been investigated which hardly provide a basis for developing well-founded recommendations for the maritime logistics. For this reason, the authors propose recommendations for action that are structured in the PESTEL matrix (Kaplan & Norton, 2008) summarized in Table 4 in six dimensions (political, economic, social, technological, ecological and legal).
5. Conclusion

5.1. Limitations
Like all other scientific papers, this article also has limitations. There is thus the possibility that not all relevant articles in the selection phase were filtered by means of keywords. There are various reasons for this, e.g. the incompleteness of the defined key words, the alternative concept names in the articles and the limitation to predefined publication outlets. The categorization of the articles also requires a substantive examination and evaluation, in which a distortion by the authors’ subjectivity is never completely excluded. This article, however, provides important new insights and discusses the current state of research on digitization in maritime logistics.

5.2. Closing considerations and implications for science and practice
By means of a systematic literature analysis, it is possible to cope with the confusing amount of practical and scientific literature in the research process. Research gaps can be identified on the basis of the current state of science, and the corresponding research needs can be formulated. In this article, the status quo of digitization in maritime logistics was discussed by means of a systematic literature analysis of published articles from scientifically representative trade magazines, books, web pages and conferences, with regard to content and methodology dealing with digitization in maritime logistics. To the best of our knowledge there is, up to now, no systematic literature analysis on digitization in maritime logistics, neither in maritime specialist publication outlets, nor in a VHB-ranked journal, although the research topic proved to be relevant. In the area of sustainable maritime transport aiming at the reduction of ship emissions by means of alternative ship propulsion, there is a corresponding need for development, since it is the topic of the future in sea transport with only a few publications in the scientific literature. The majority of the publications are research results in specialist journals and specific conference volumes. A large part of the publications was also found in the so called grey literature. The study and its results show that practice recognized the development potential. Nevertheless, research is still at an early stage. On the one hand, there is a lack of theoretical studies that examine in more detail the future behavior of actors in the maritime logistics chain. On the other hand, alternative explanatory approaches to recommend appropriate action and restructuring are missing. We therefore recommend to expand this research into areas where information and big data projects have already been implemented. The aim of the research in this area is to provide robust contributions to theory that are characterized by high and clear predictive power of expression and as well as theoretical interpretations. These artifacts could be achieved by methodological and theoretical triangulation.

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Notes
1. Twenty foot Equivalent Unit. Abbreviation TEU. 1 TEU corresponds to a 20-foot standard ISO container.
2. AIS = Automatic Identification System is a radio system that improves the safety and control of ship traffic by exchanging navigation and other ship data.
3. A feeder ship (from the english word to feed) is a cargo vessel specially built for container and car transportations, which acts as a supplier and distributor for large seagoing vessels and seaports.
4. Marine Pollution—International Convention for the Prevention of Marine Pollution from Ships.

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