5.1 Introduction

According to UNCTAD [1], international shipping industry is responsible for 80% of world trade. Rose [2] states that shipping moves 90% of all the good transported worldwide. Without shipping, intercontinental trade; the transportation of bulk, raw materials; and the import/export of affordable food and manufactured goods simply would not be possible.

Therefore, it is important to identify and address the challenges international shipping industry has to face in the next couple of years. These challenges include, among others, reduction of greenhouse gases, lack of suitably trained and experienced marine personnel, increased demands for safe operation and minimizing the number and consequences of accidents. In general, these challenges can be addressed by developing and integrating digitalization, automation and introducing automation technologies on board ships and ashore (e.g., Danish Maritime Authority [3]). These smart technologies represent great potentials, for example, to increase fuel savings by new means of propulsion. It also may enhance the safety for the crew by
simply reducing the number of crew or even providing the opportunity to operate a ship unmanned, just monitored by an operator from ashore.

Despite all those expectations and outlook, it is necessary to have a look at the present maritime law and determine how all these new technologies, especially for autonomous or remotely controlled ships, can meet all the requirements. Another highly important issue is the training standards for marine personnel on board as well as ashore. The integration of remotely controlled or even autonomously navigating ships requires, among others, a shift of responsibilities and, obviously, a substantial change of skills of operators and other stakeholders involved, e.g., in Maritime Authorities and VTS centers [4].

This paper focuses on the implementation of smart operating systems and discusses their potential impact on legal, operational, and educational issues in the maritime sector on a very basic level. A draft research strategy will be suggested in order to identify maritime legal issues, issues regarding the standards of education and training for seafarers, and also to discuss possible impacts on future modes of operation of ships. The research will take into account pilotage, traffic monitoring stations, and ship-shore/ship-ship communication respectively.

5.2 Maritime Transportation: The System’s Perspective

Components and Actors

Each transportation system, basically, can be structured into five main components and can be applied to every transport mode (i.a., [5]) to describe processes, functions, relations, and dependencies. For providing common understanding, a descriptive model is developed below.

Transport Means Every transport mode has a specific means for moving goods from origin to destination, e.g., cars, lorries, trains, and airplanes. In the maritime system the transport means are ships of varying dimensions and types for numerous purposes. The basic division we need to take into account is between commercial and non-commercial ships.

Drivers Drivers, in principle, are the persons who are in charge for steering and controlling the transport means. In shipping, this is usually the captain with his team of navigating and technical officers and especially the respective Officer of the Watch (OOW) on the ship’s navigational bridge. In certain cases, especially when navigating in challenging sea areas, a pilot is providing navigational assistance to support her or him.

Transport Ways Transport ways or paths are the highways, roads and streets, railways, air traffic corridors, etc. In the maritime transportation system, these are the open sea and coastal areas, as well as the river and other inland navigation waterways, canals to harbors and port terminals.
Traffic Organization and Administration  Components for traffic organization and administration cover the activities of the dedicated and recognized international, regional, and national institutions responsible for developing, negotiating, and establishing the set of rules and regulations including also legal and technical standards. The system’s component “Traffic organization and administration” is to represent the system’s components providing overall legal frameworks for a globally harmonized implementation and enforcement of rules and standards. In the maritime transportation system, we consider the International Maritime Organization (IMO) as the main global body, accompanied by, among others, the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), the International Chamber of Shipping (ICS), the International Association of Classification Societies (IACS), and other international but also intergovernmental, nongovernmental, and further maritime organizations. On a regional level, there are continental organizations like the European Maritime Safety Agency (EMSA) or Australian Maritime Safety Authority (AMSA) relevant actors under this subsystem. On a national level, the waterway and shipping administrations (like e.g. Danish or Swedish Maritime Administration) together with their related agencies and other bodies take action to ensure implementation and enforcement in their respective areas of jurisdiction.

Traffic Management  A system component that is becoming more and more important in every transport mode is traffic management. Nowadays, every transportation system operates increasingly sophisticated traffic management systems reaching from provision of basic information up to advanced support to ensure safe and efficient flow of vessel traffic. This component covers sub-systems, e.g., Vessel Traffic Services (VTS) with its different services but also Pilotage, Search and Rescue, Maritime Assistance, Ice Patrol, and other commercial or noncommercial maritime services provided from ashore.

All components of the system are linked and interact with and affect each other. Overall aim of all the components’ activities is to serve the safety and efficiency of maritime transportation.

Reviewing Ongoing Developments

Presently the maritime transportation system is undergoing substantial changes including the introduction of disruptive technologies requiring adequate action and modifications in the system and its components. Major examples for such substantial changes are the introduction of new technologies basing on substantial and sustainable digitalization and the development and implementation of the e-navigation concept.

Digitalization  The fourth industrial revolution, also known as Industry 4.0, is, among others, driven by Internet, advanced technologies, and a network of smart
systems and products. It includes technology of robotics, autonomous decision-making tools, and applications using augmented and virtual reality. The Industry 4.0 has already affected several domains connected to maritime logistics [6]. The concept is driven by digitalization and optimization of industrial processes that use the new emerging technology [7, 8].

Actors from all components of the maritime transportation system are involved in the digitalization process, ranging from ship and port management, waterway and port authorities, terminal operators, shipping companies up to truck and railroad companies. Sharing data between all actors is improving the traffic flow on the waterways, resulting in less waiting times for the ships and more efficient cargo operations in ports and hinterland transportation [8]. Moreover, Jahn and Saxe [9] are suggesting that only a network of interconnected ports can improve efficiency, reduce cost, increase reliability, and decrease waiting times for ships.

New technologies will not only improve the supply chain and maritime logistic processes but will improve the monitoring of traffic flows and cooperation between ship and shore as well. With new technologies and further developments in the marine surveillance sector, many shipping companies are already operating and monitoring their fleet with Fleet Operation Centres (FOC). Shore-based operators provide additional information and warnings to the ship. The operator may even be allowed to give recommendations or instructions [10].

e-Navigation e-Navigation is a concept developed by IMO and IALA. The concept is clearly focusing on the human operators on board the ships (e.g., OOW) and ashore (e.g., a VTS operator). It is aiming at “the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.” A Strategy Implementation Plan has been agreed by IMO at 94th session of MSC in 2014 and is set into force. There are many ongoing initiatives to implement the concept by testing new applications in e-Navigation test beds. The e-Navigation concept and its implementation are primarily basing on digitalization and consequent use of latest information and communication technologies [11, 12].

Digitalization and e-Navigation require not only adaptation of logistic processes but, moreover, further development of job profiles and existing training and education standards and schemes of maritime studies’ syllabuses and course curricula, respectively.

MASS and Autonomous Shipping Maritime Autonomous Surface Ships (MASS) is the IMO’s term addressing the recent developments heading for autonomously navigating and once maybe unmanned ships. Even though, autonomous or remotely controlled vehicles or ships are not a new idea. Autonomous or remotely controlled underwater vehicles are already common in marine geoscience for quite a time. They are in use for military, commercial, or scientific research. MASS is expected to be the next step in the transformation of the maritime transportation system. Digitalization and e-Navigation will contribute to increase the level of autonomy.
and will allow introducing unmanned and even autonomously navigating ships into the existing traffic system from the perspective of technical feasibility. Legal frameworks to provide the adequate legal background are under development. This new transport means will come along with further monitoring and remote operation facilities like shore control centers [13, 14].

5.3 Traffic Monitoring and Control: Today and Tomorrow

State of the Art

Today’s traffic management is a result of the development of shore-based Vessel Traffic Services (VTS) [15]. Originally introduced, among others, to ensure safe approach to and from harbors under conditions of restricted visibility by providing radar-based navigational information from shore to ships, VTSS nowadays provide Information (IS), Navigational Assistance (NAS), and Traffic Organization Services (TOS). VTSs are part of SOLAS. According to IMO resolution A.857(20), VTS is defined “as a service implemented by a competent authority, designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in a VTS area.” This resolution, however, is under revision mainly to modernize and adapt resolution to common practice.

IMO’s activities are strongly supported by IALA, who has undertaken huge efforts and has provided numerous guidelines and recommendation for efficient establishment and harmonized operation of VTS around the globe. VTS, clearly, is a risk management tool that functions like a control loop, as depicted below (Fig. 5.1).

Usually, a VTS works in national waters of a coastal state. It collects traffic and environmental data through its sensor infrastructure and interacts with vessel traffic by voice communication through VHF by sending out information at regular times or on demand, giving recommendation or advice to support onboard navigation processes and even may intervene by giving instructions, if needed, e.g., to contribute to avoidance of collisions and groundings. However, the final decision always remains with bridge team on board [16].

Besides VTS there are meanwhile further shore-based monitoring bodies established, namely, so-called Vessel Coordination Centers (VCC) as well as Fleet Operation Centers (FOC).

A sample of a VCC is the Hamburg Vessel Coordination Center (HVCC). It is operated by Hamburg port authority and coordinates ship movements inside the port terminals. Moreover, the HVCC also provides support to captains and shipping companies when they are leaving their last port of call and heading for Hamburg. The VCC provides passage plans taking into account, e.g., tidal conditions on river Elbe and expected traffic to organize smooth passage avoiding delays that may be caused, e.g., by meeting at fairway bottlenecks.
An FOC is a company owned facility and monitors the safe progress of ships of its own fleet. FOCs use most modern data communication links and have installed same navigational tools and displays ashore as they are on board. FOCs act as an additional safety barrier and have continuous connection to the members of the bridge team. Shore-based operator in a FOC may even know the bridge team members on board.

Fig. 5.1 Risk management by VTS presented as a control loop

An FOC is a company owned facility and monitors the safe progress of ships of its own fleet. FOCs use most modern data communication links and have installed same navigational tools and displays ashore as they are on board. FOCs act as an additional safety barrier and have continuous connection to the members of the bridge team. Shore-based operator in a FOC may even know the bridge team members on board.
Participant observations as part of field research are ongoing and include visits to VTS centers along the coasts of North and Baltic Sea as well as the fairways to ports. First preliminary observations and interviews indicate that, although the services are provided according to the same basis of operational procedures, there is a wide variety of different tasks and services are sometimes carried out differently. A main reason for this is the specific conditions of the monitored area in terms of the fairway conditions and the partly different specific rules. On the other hand, it is observed that services are provided with highest ambitions to take into account the specific characteristic of the concrete situation (type of ships, rules, environmental conditions, and much more). Similar to the rules of the “International Regulations for Preventing Collisions at Sea,” it is valid that exact sequences of actions and measure a VTS operator shall give cannot be provided for each and every specific situation and challenge skill, knowledge, and experience of the operators. Similar results have been generated recently in empirical studies in other regions [17, 18] as well.

**A Future’s Scenario**

Assuming that shipping will continuously develop like before the covid-19 times, where ship’s dimensions were growing and the navigable space becomes more and more limited by other new users, e.g., renewable energy installations, fish farming, and others, the need for long-term coordination of traffic will further increase. The need for the protection of the marine environment will need to be supported by reducing emission of greenhouse gases to a minimum or even to zero.

On the other hand, composition of vessel traffic in future will include ships equipped with most sophisticated propulsion systems for high maneuverability; ships might sail with minimum crews but can be unmanned. Conventionally navigating ships will share navigable space with ships monitored by the company’s FOC and may be even controlled from the remote SCC [13, 14]. Several research studies are ongoing to provide input for such future developments [19–21].

**5.4 The Shore-Based Operator’s Perspective**

Besides the technical issues in shipbuilding, vessel traffic, and ship navigation, it is of utmost importance to consider changing the port’s infrastructure as well. Moreover, yet importantly, there is obvious need to consider operational issues of how to organize the regimes and interventions of a VTS and to coordinate their measures with those of VCCs and FOCs respectively. These essential operational issues will also need to be taken into account for future training and education schemes.
The autonomous or remotely controlled ships have to “communicate” with the fairway’s infrastructure such as dolphins and light buoys and port authorities to get the information they need. Communication is also necessary with VTS and pilots on conventional ships, e.g., to know if they are on the right track and if they have to slow down due to traffic congestion in the harbor and to get the information about their berth or jetty [9].

**Transition from Navigators, Pilots to Shore-Based Operators**

The progress of automation does not only change technical standards in the industry but has an influence on the human-machine interaction in the same way [22]. The automation progress in the shipping industry had many advantages, such as reducing the number of crew on board from 30–40 in the 1970s and 1980s to presently 10–20 and increasing the overall safety of ship operations [22]. Nevertheless, seafarers are trained to interact with the technology on board and make decisions based on their experience and evaluation of all elements [23]. In the process of navigation, the captain or OOW has an active role in maneuvering and steering the ship. The person in charge of navigation is aware of his surroundings and is still obliged to check the situation by finally looking out of the window and applying the rules of good seamanship (Fig. 5.2).

However, when reducing the number of crew on an autonomous ship to a minimum, for instance, four to five or even none, the ship is playing an active role in the navigation process. The autonomous ship navigation system, among others, needs to be programmed to detect and classify certain objects in its surrounding area according to a programmed algorithm [24]. The algorithm needs to be able to classify, prioritize, and assess certain information given by electronic sensors and signals from the onboard system or other ships in the area to navigate the ship like a human operator [25].

The same concept of information processing applies for the remote human operator. He needs to be able to get all the information, evaluate their meaning, and predict the outcome of the situation [23]. Nevertheless, most of the time, the operator (on board or ashore) will switch to a passive role, where he is just monitoring the Autonomous Navigation System.

**Fig. 5.2** Human operators in the maritime transportation system (left, bridge team on board a container vessel; right, operators in VTS center Singapore). (Photos: author)
Need for In-Depth Studies to Adapt Maritime Training and Education

The potential development briefly described and discussed in the above paragraph highlights the urgent need for comprehensive research into the modernization and adaptation of the existing MET schemes. Necessary skills and knowledge of operators in the future maritime transportation system need to be reviewed and carefully determined. Until today, many organizations value the skills, knowledge, and experience of mariners when recruiting for positions ashore. Applicants for pilot’s or VTS operator’s positions shall have preferably a master’s license and several years of experience as a captain or at least as a chief mate. This is similarly valid for training instructors and lecturers of cadets. However, institutions increasingly lacking appropriate applicants matching those requirements. Consequently, a fundamental question to answer is: will we have in the future experienced mariners, who will undergo the traditional training programmes to become a pilot or a VTS operator or do we need to rethink and to adapt and to change MET to completely new profiles of applicants, with less or even no seafaring experience at all? And, consequently, how to compensate missing seafaring experience?

If operators in the future just rely on displays of technical data and not question the outcome, it may result in major accidents, such as the collision between two ships in the fjord of Kiel in 2014. The navigating officers on both ships trusted the ECDIS data and did not realize that there was a GPS failure [26]. These failures are described as an “out-of-the-loop unfamiliarity” [22]. Due to the advanced technology on board ships, the navigating officers or captains are already taking over the passive role and just monitoring data given by the RADAR, ECDIS, AIS, or other bridge equipment. Over the time this can lead to a possible skill loss, and decisions in case of emergencies (collision, grounding, etc.) will be harder to make by the ship handler [22]. In respect to maritime safety, seafaring experience and good seamanship are considered to be most essential today. If this is true and shall remain in future, then we need to exactly know why seafaring time is needed and to what extend. If we cannot ensure sufficient practice times, then we need to ask how to compensate, e.g., by simulation-based training? Moreover, if we found, it is impossible to compensate, then we need to study what other skills and knowledge of the younger generation have potential to replace them.

To answer such questions, research studies are ongoing, applying qualitative and quantitative methods, in order to determine the need for a change in the skill set of marine personnel, handling and operating ships, as well as evaluating the possibility of unmanned autonomous or remotely controlled shipping within the coastal area of a coastal state. The focus will be laid on evaluating training standards for seafarers and communication processes (e.g., ship-ship and ship-shore) and proposing necessary changes. The research aim and objective are defined by applying the SMART (specific, measureable, attainable, relevant, and time-bound) rule [27].
5.5 Conclusion and Outlook

A holistic system’s approach to study the existing maritime transportation as is has been carried out. It highlights the connections and interrelations of the single components of the maritime transportation system. The research developed a future scenario, specifically focusing on shore-based infrastructures for monitoring and controlling vessel traffic taking into account the introduction of potentially unmanned and autonomously navigating ships.

Basing on participant observation, expected changes of the existing regime for shore-based services are suggested and discussed. Main focus of the studies is laid on the shore-based perspective and potential changes in relation to the human operators in the loop for monitoring and controlling the traffic flow.

Basing on expected changes, driven by technological developments, the need for corresponding operational changes has been elaborated and the need for adaptation of the existing schemes for maritime education and training is indicated and briefly discussed.

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