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Editorial

Applied Maritime Engineering and Transportation Problems 2022

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1. Introduction

It is probable that the term marine traffic engineering (MTE) was first used by Toyoda and Fuji [1] in 1971, who defined it in the *Journal of Navigation* as "the study of ship traffic and the application of the results of this study from the improvement of port infrastructure and traffic organization".

The first quantitative estimation of marine accident safety was presented by Fuji [2] who studied accidents in the Urga Strait. Interestingly, when compared to Fuji's study, the currently accepted collision probability value has decreased significantly (from an accident probability value per operation of 10^{-4} to 10^{-5} today). Fuji [2] estimated the probability of grounding as $10^{-3.7}$, which is also higher than the currently accepted values. In this paper [2], Fuji also identified the size of a ship's domain and assumed it to be an ellipse with the parameters of 6 L × 1.5 L.

Later research focused on the creation of accident models, of which the McDuff model [3] is now widely used. The MacDuff model distinguishes between geometric probability (resulting from the geometry of the ship's passage) and causal probability, defined by some authors as human error. Various general regression models of navigation safety in maritime and port areas are currently being developed based on the analysis of a large number of real-time ship-maneuvering simulation results [4]. Further research on ship domains was based on the theoretical basis provided by Goodwin [5].

Currently, research is being carried out that involves automating the processes of domain extraction from real-world data, including primarily using AIS [6]. These methods are mainly applied to coastal waters, and the resulting domains are mainly used for safety management or early notification of navigation incidents [7]. At the same time, advanced methods are being developed for processing AIS-derived data to support ship navigation [8].

In a significant number of marine traffic engineering issues, the ship maneuver simulation method, including the real-time method, is one of the most suitable methods for solving the associated research task. This is because this method is characterized by the following characteristics [9]:

- A high degree of compliance with reality;
- Low financial expenditure compared to the use of physical models;
- The possibility of studying non-existent systems;
- The possibility of simulating random processes.

Several unsolved problems that occur when ships exceed the capacity of the port infrastructure were identified by Perkovic et al. [10]. Guidelines [11–14] address the issue of waterway design by standardizing the design process itself. In parallel, one can observe the intensification of national and regional policies on the issue of waterway

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design by means of ship-maneuvering simulations. Ports are also the subject of strategic risk assessments [15,16]. General principles of port and waterway design for ships are presented in various studies [17,18]. Simulation research methods can also be used in other aspects of shipping safety like designing risk-based port regulations [19]. Assumptions for real-time simulation methodologies for waterway and port design are outlined in recent PIANC [11,12], ROM [13], IALA [14] and Japanese guidelines [20]. An exemplary comprehensive study in this area, particularly for the position distribution of ships on a waterway, was presented by Iribarren [21].

The process of designing waterways based on real-time computer simulations depends strongly on the experience and knowledge of the simulation team. In the marine simulation sector, compared to other transportation branches such as aviation or road engineering, there is still more "freedom" and discretion in the design process itself. Expert knowledge supported by pilots is usually the key factor here for simulations based on their previous design. Benedict et al. [22] developed computer support for evaluating and assessing the results of ship-handling simulator exercises, but dedicated mainly to training ship-handling simulators. In the navigator's decision-making process, the ship's waterline position predictors, which are also quite common on board and are usually achieved in an ECDIS environment, are very useful [23].

Zhang [24] presented a comprehensive study on the evaluation of the competence of seafarers trained on ship-handling simulators to manage the bridge team in the implementation of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention).

Sarioz and Narli [25] presented the results of a real-time ship-maneuvering simulation and its evaluation in their study of the maneuvering performance of large tankers in the Bosphorus Strait.

Inoue [26] developed a quantitative model for evaluating the difficulty of maneuvering a ship caused by the limitation of maneuverability in this maneuvering area or congestion or a combination of both. It includes acceptance criteria based on the seafarer's perception of safety.

Lataire et al. [27] presented a systematic study of ship maneuverability in restricted waters. This research was conducted by Flanders Hydraulics Research (FHR) and Ghent University (UGent) using five different simulation techniques, including real-time human-controlled simulation and accelerated simulation.

A classification of marine ship simulators was presented by Cross and Olafsson [28], where they considered standards based on DNV classification.

Donatini et al. [29] described the results of a study conducted by the authors to assess how hydrometeorological conditions are currently modeled in ship-maneuvering simulators. They found that while mathematical models for ship-maneuvering behavior are well documented in the literature, a review on hydrometeorological modeling does not yet exist. The results are based on an extensive survey of simulator end-users. Several types of studies have been conducted on the effects on ship models implemented in ship-handling simulators of wind [30], waves [31], ice and current [32]. Delefortrie and Vantorre [33] provided an overview of research and practical applications of ship behavior and modeling in areas with ultralow under the keel clearance.

Faster time simulation (FTS) is a widely accepted method for preliminary studies in port design and approaches. The state of the art in this field was presented by Benedict [23]. The disadvantages of FTS include the autopilot capabilities, which differs when compared to the helmsman or pilot, and the problems with the automatic control of tugs.

At the same time, there are a number of guides and recommendations for using simulators for waterway design [17,18,34], as well as monographs [35–37] and review articles [38–40].

A comprehensive study of the impact of port infrastructure upgrade on the efficiency of port operations is presented in [41].

Nowadays, marine traffic engineering is treated more broadly as a scientific and technical field that deals with the planning, design, implementation and management of vessel traffic and other aspects of marine navigation to ensure the safe, efficient and economic operation of marine waterways.

It is an interdisciplinary area of knowledge with a high degree of complexity, covering a wide range of issues related to safety, logistics, environmental protection and the use of modern technologies in marine navigation. The main research directions in this field are as follows:

1. Maritime traffic management, which includes the optimization of shipping routes and traffic management in ports and on the high seas, including vessel traffic service (VTS) systems that monitor and direct ship traffic to ensure safety and smooth traffic flow.
2. Shipping safety, including a team of studies on preventing collisions at sea, analyzing risk factors, developing warning and emergency response systems, as well as developing safety standards and evacuation procedures.
3. Protection of the marine environment, which focuses on developing methods and technologies to minimize the negative impact of shipping on the environment, including reducing emissions of harmful substances, preventing oil spills and other pollutants, and protecting marine wildlife.
4. The development of new technologies, i.e., the introduction of modern technological solutions in the field of navigation, communication between ships and land, and automation, which enable safer and more efficient maritime operations. This includes the development of autonomous ship systems, the use of maritime drones and the use of artificial intelligence.
5. Port and maritime infrastructure design, including optimizing the design and layout of port infrastructure and maritime waterways to enable safe and efficient vessel traffic, and developing projects that increase the capacity of ports and shipping corridors.
6. Logistics and supply chain management, which focuses on the integration of shipping into global supply chains and the development of logistics management methods to optimize the movement of goods through seaports, including the use of information technology for supply chain management and real-time data sifting.
7. Adaptation to climate change, including studies of the impact of climate change on shipping, including sea level rise and its impact on port infrastructure and changes in shipping routes due to melting glaciers. This also includes developing adaptation strategies for ports and waterways.
8. Crisis management and emergency response, that is, the development of emergency management systems for spills of harmful substances, rescue operations at sea and in ports, and strategies for minimizing the effects of maritime disasters.

These lines of research are essential in developing and maintaining sustainable, safe and efficient shipping operations around the world. As technology advances and the global environment changes, marine traffic engineering will continue to evolve to meet the new challenges and needs of the maritime industry. Figure 1 shows the broad and narrow definition of MTE.

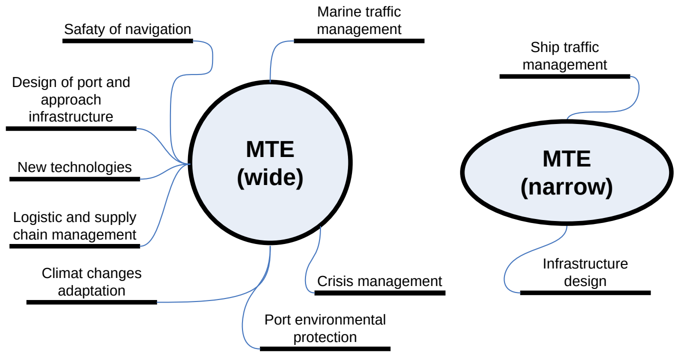

Figure 1. The broad and narrow definition of MTE.

2. Published Articles

Author Contributions:

In Contribution 1, the authors present a study that explores the use of polymer–hemp composites as a sustainable alternative to polymer–glass composites in small-vessel construction, assessing their fire resistance and recycling potential compared to traditional materials.

Contribution 2 develops and evaluates a long-short term memory (LSTM) network model to predict marine accident frequency, finding it more accurate than traditional methods and linking accident occurrence to specific times during the third officer's duty.

Contribution 3 evaluates the effectiveness of different estimation methods in processing data obtained from six evaluated GNSS receivers. The major finding of the paper is the novel condition-bound adjustment method which outperforms ordinary least squares estimation in precision surveys.

Contribution 4 discusses the optimization of liquid-level control in ship fuel tanks using standard PID controllers and a modified Dahlin algorithm, demonstrating the latter's superior performance in reducing control signal "ringing" and achieving desired system behavior.

Contribution 5 addresses the processing of experimental crude data in nautical measurements, enhancing traditional histogram structures with fuzzy systems to extract conditional dependencies and improve data accuracy for position fixing.

Contribution 6 details a method for estimating the time required for bathymetric measurements using multi-beam echosounders in hydrographic surveys, considering factors like water depth and swath angle, and is informed by over twenty years of experience aboard the Polish Navy hydrographic ship Arctowski.

Contribution 7 introduces a new method for determining safe passing distances on two-way fairways, addressing the shortcomings of existing models by incorporating modern simulation research with an FMBS-type simulator and refining the widely used MTE method based on the results from tests on various vessel types and fairway conditions.

Contribution 8 presents an enhanced ship trajectory prediction model, the WOA-Attention-BILSTM, which integrates an attention mechanism and Whale Optimization Algorithm with a Bidirectional Long Short-Term Memory model to improve accuracy and applicability in maritime transportation, demonstrating superior performance in collision avoidance and route planning compared to traditional models.

Contribution 9 assesses the effectiveness of a multitask navigation bridge simulator, specifically the K-Sim Polaris, in automatically evaluating navigators' anticollision actions through simulations involving students and experienced officers, along with expert input, to refine assessment criteria and testing scenarios for more objective evaluations.

Contribution 10 explores the impact of autonomous technologies on maritime education, focusing on the evolving roles of seafarers as defined by the International Maritime Organization's levels of autonomy, through a systematic review that assesses the current state and trends in training for maritime autonomous surface ships (MASSs) and highlights key educational adjustments needed for adapting to these changes.

Contribution 11 evaluates the positioning accuracy of a surface vehicle (SV) using various methods, including Dead Reckoning (DR), Geodetic Least-Squares Adjustment (GLSA), Geodetic Robust Adjustment (GRA), and External Kalman Filter (EKF), demonstrating that GRA and EKF significantly improve accuracy, reducing the Root Mean Square (RMS) error from about 9 m to as low as 1.14 m when optimally interchanged.

Contribution 12 analyzes a ship's rolling motion from three perspectives, studying the effects of external forces, successive beam seas, and wave direction on a moving ship, and introduces 3D maps and polar diagrams as guidelines to help shipmasters quickly adjust speed when faced with changing sea conditions to achieve optimal stability.

Contribution 13 evaluates the terrestrial Ranging Mode (R-Mode) system, an alternative to GNSS using medium-frequency (MF) radio beacons for maritime navigation, and analyzes its accuracy in the southern Baltic Sea, finding a significant decrease in precision under ionospheric interference, with implications for further system development.

Contribution 14 calculates the accident reduction rate (ARR) associated with the Marine Transportation Security Act (MTSA) by using geographic information system technology for spatial analysis and the synthetic minority oversampling technique with a random forest algorithm on maritime accident data, determining an ARR of 17.41% that quantifies the safety benefits of expanding MTSA's scope.

Contribution 15 explores the impact of the Port of Gdynia's operations on local road traffic, specifically the effect of heavy goods vehicles (HGVs), using traffic data and PTV Vissim software for modeling and analysis, and proposes an optimal solution for enhancing the transport network around the port based on the findings.

3. Future Applications and Approaches of MTE

Marine traffic engineering (MTE) is a professional activity associated with the planning, design and management of traffic on the seas and oceans. It is an essential control activity for the safety, efficiency and environmental protection of shipping. With the increasing globalization of international trade and heightened environmental awareness, there are further opportunities and diversification of potential advances in this area. The following trends and opportunities are emerging in the industry:

1. Improving automation and remote control with autonomous vessels and unmanned navigation systems will be further developed to autonomously save operating costs and increase safety. This will occur alongside the future development of artificial intelligence and machine learning, which can be used to create more intelligent navigation systems that can better predict hazards for optimized shipping routes.
2. Cybersecurity, which focuses on the digital dependency of technologies and communication systems, encompasses higher aspects of cybersecurity that need to be in place. The he data security systems to protect from cyber-attacks will be an indispensable part of maritime transportation technology.
3. Environmentally friendly technologies used to protect the marine environment and decrease emissions will become increasingly important. Innovations in alternative fuels such as LNG (liquefied natural gas) or hydrogen and technologies to reduce emissions will be crucial for sustainability in shipping.
4. Integrated maritime traffic management systems enable the development of integrated platforms that combine data from different sources (satellites, AIS and radars) to cover a broader range of maritime information. They help to manage shipping traffic better and thus reduce the likelihood of collisions.
5. Education and training require an interdisciplinary approach that focuses on technological developments in all shipping areas and realigning existing education and training courses. One of the most important aspects is the interdisciplinary approach to training marine engineers, including all types of technical and ecological problems related to the aquatic environment.

6. International cooperation, as one of the most important issues in shipping operations, is the global nature of shipping, which reflects daily growing complexity. Global regulation and cooperation are the only possible solutions in the sense that efforts to harmonize regulations and standards globally are necessary for success in ensuring the safety of shipping worldwide.

Further development of shipping technologies in the future should focus on highly integrated human-machine coexistence technologies providing greater safety and efficiency in maritime operations. These will be developed taking into account the protection of the marine environment and respect for our planet's resources.

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