



Core Aspects of Timing in a Ship Voyage Charter: Shipowners Perspective

Oleksiy Melnyk^{1*}, Yuliia Koskina¹, Svitlana Onyshchenko¹,
Aditya Rio Prabowo², Martin Jurkovič³, Oleksii Drozhzhyn¹
Nataliia Pavlova¹, Vladlen Kyselov⁴

¹Odesa National Maritime University, Odesa, Ukraine

²Universitas Sebelas Maret, Surakarta, Indonesia

³University of Žilina, Žilina, Slovakia

⁴Cherkasy State Technological University, Cherkasy, Ukraine

Abstract

Maritime freight transportation plays a key role in global logistics, ensuring the transportation of goods between countries. One of the important elements of this process is the voyage chartering of vessels, which regulates the relations between shipowners, charterers and other participants of transportation. The article examines the structure and time stages of a charter party from the perspective of a shipowner. The sequence of the main stages of a voyage is described, and an analysis of documentary support for operations in ports of loading and unloading is provided. Particular attention is paid to the formalization of key points, such as submission of readiness notifications, accounting of time spent in the port and procedural aspects of interaction with port authorities. The results of this work aim to improve voyage time management practices and reduce commercial risks associated with maritime transportation.

Keywords: charter party, chartering, ship voyage, cargo operations, laytime, shipowner, shippers, consignee, maritime transportation, port of loading, discharging process, shipping technology, statement of facts, shipping and transportation safety.

1. Introduction

Relationships of parties in the transportation process are built based on signed agreements on the rights and obligations of the parties, which must be established based on current international regulatory legal documents, national legislation, existing rules and customs. In the process of cargo transportation, parties shall provide cargo with necessary documentary support, tare, marking, development of conditions for transshipment, transportation, and storage in order to ensure a safe maritime transportation process. Voyage time calculation plays an important role, since the parties

* Corresponding author: Oleksiy Melnyk (m.onmu@ukr.net)

are interested in the reduction of the time required for cargo operations, where the charterer is concerned about the absence of additional payments and the shipowner is focused on the agreed period of operations for further effective and optimal use of the vessel.

When studying voyage chartering of vessels, much attention is paid to analyzing commercial aspects, time characteristics of sea transportation, and organization of loading and unloading operations. Mazioli et al. (2019) investigated the impact of charter party provisions and port characteristics on the financial performance of port operators, emphasizing the importance of clearly regulating the parties' interaction in charter agreements. Holliday (1993) examined the role of the oil industry and charterers in port and shipping management practices, which provided a basis for understanding commercial interaction in the industry.

Additionally the studies by Georgoudakis et al. (2025) and Beullens et al. (2023) focused on the relationship between ship energy efficiency and time charter terms, while Taylor (1982) and Wilmsmeier (2012) discussed how operational and infrastructural factors affect the efficiency of voyage planning and fuel-related decision-making. The legal aspects of voyage charters, particularly in the context of risks associated with emergencies (Boviatsis, 2022; Sayed & Akter, 2022), remain essential for protecting the financial interests of shipowners.

At the same time, Basok et al. (2024) and Shestopalov et al. (2024) analyzed the technical and energy-efficiency constraints influencing ship operations, while Budashko et al. (2020) and Golikov et al. (2018) proposed engineering approaches for modeling vessel parameters and positioning systems under dynamic conditions. From a managerial perspective, Bastug et al. (2016) and Nikitakos & Lambrou (2007) explored how digitalization and access to information sources affect ship chartering efficiency, aligning with the modern trends in e-chartering and smart logistics (Plomaritou et al., 2022; Batrinca, 2007).

The legal risks associated with demurrage in voyage charter parties are analyzed in detail in the studies by Akarachotikavanith (2015) and Plomaritou & Nikolaidis (2016), which is of particular relevance to this study in the context of accounting for parking time. In addition, Lapkina and Malaksiano (2016, 2012) investigated the optimization of port equipment and the stability of economic indicators of port operations, showing their impact on the timing and cost parameters of voyage performance.

A number of studies have been devoted to optimizing the allocation of vessels in liner shipping (Chen et al., 2008; Tan et al., 2021) and developing decision-making models for ship chartering (Kiseleva et al., 2022; Turoń et al., 2019). Nokkala et al. (2012) evaluated the external effects of extreme weather on transport timing, highlighting climate-related uncertainty in voyage scheduling. Cariou and Wolff (2013) also made a significant contribution to the study of chartering practices by analyzing the peculiarities of chartering in liner shipping.

Other sources, such as Melnyk et al. (2024, 2023), Shumylo et al. (2023), and Sherstyuk et al. (2016), focus on ship safety, team interaction, and structural modernization, which indirectly affect voyage efficiency and compliance with contractual obligations. The study conducted by Kurennov et al. (2022) aims at developing and applying mathematical models for the examination of technical readiness of the vessel, which may indeed be of importance for shipowners with respect to fulfillment of charter obligations in time.

Nagurney et al. (2024) illustrates that the combination of agricultural cargo insurance with war risks may be used to curtail unanticipated delays in the execution of voyage

charters, while Popova & Popov (2023) and Cernisevs et al. (2023) stress intelligent management and risk-based selection of key performance indicators as enablers of productivity and reduction in time deviations in shipping operations. Zhikharieva (2025) highlights the importance of intangible assets, in particular reputation and relationships with counterparties, as factors affecting the timely fulfillment of charter obligations, while Melnyk et al. (2023) propose a simulation approach to forecasting changes in the seaworthiness of a vessel under the influence of various factors, which allows shipowners to plan voyage times more accurately and minimize the risk of delays.

Similar approaches to voyage event formalization and laytime calculation have been previously discussed in maritime operations research. For example, Kiseleva et al. (2022) and Onyshchenko et al. (2016) applied temporal logic to port call event analysis, while Mazioli et al. (2019) and Boviatsis (2022) integrated contractual constraints into automated decision-support tools. These studies provide a methodological background for the present work.

Thus, the literature review demonstrates the complex nature of research in the field of ship chartering, where commercial, technical, and legal aspects are interrelated and require integrated analysis to enhance the efficiency of maritime transportation. Reviewing existing literature on the topic allowed for the study of differences between current theoretical frameworks and highlighted the need for a new approach to the voyage chartering process, its structure, the sequence of implementation stages, and the establishment of connections between theories and their practical application.

Even though the nature and pattern of relations between market participants seem to be clear and unquestionable. The shipowner is responsible for cargo loading on board the ship, its stowage, and safety during transportation and delivery to destination ports, stevedoring and freight forwarding companies, respectively, in charge of cargo operations, storage in port warehouses, and delivery to the consignee. However, the practice shows that there are situations that require proper monitoring of recording the ship's time and control over observance of certain principles and methods of commercial matters in the maritime transportation process is of great interest and often causes disputes and discrepancies between the parties. It concerns the issues of freight documentation in terms of cargo acceptance or delivery, clauses in the terms of ocean freight contracts, observance of international agreements and national laws which regulate mutual relations of the parties in the logistic system "shipper - port of loading - vessel - port of discharge - consignee". A special role in this chain is given to the shipowner and assertion of his interests in case of abnormal situations in maritime transportation.

The purpose of this article is to analyze the time aspects of voyage chartering of vessels, taking into account the peculiarities of interaction between the parties in maritime transportation and documentary support of cargo operations. In contrast to existing studies, this paper focuses on formalizing the sequence of documentary procedures and time points of a sea voyage using logical operators, which allows for a more accurate assessment of downtime and cost risks during voyage chartering.

The scientific novelty of the work is the formalization of the sequence of stages of a sea voyage using temporal logic operators, which allows for a more accurate assessment of the time parameters of a ship's berthing in a port and effective management of costs associated with delays. Additionally, documentary procedures for vessel arrival and departure from the port have been generalized, which helps to increase the transparency of interaction between the participants in maritime transportation.

2. System Description and Methodology

Global freight market of tramp vessels is a perfectly competitive market, unlike the linear form of shipping, as there are many sellers and buyers of homogeneous products acting independently of each other; neither of which can significantly affect the level of freight rates, and neither has enough complete information about prices and costs. The tramp freight market is sensitive to changes in supply and demand, and significant fluctuations in freight rates characterize it. The direction and length of cargo flows influence the technology of their processing and the intensity of transportation, which, in turn, has determining commercial conditions for charters. Considering significant distances of transportation, it also determines a high share of transportation costs in the price of goods. To reduce the level of freight, it is necessary to improve sea-going ships and increase their technical handling intensity.

Shipping is the most efficient and cost-effective way of international transportation of goods, and the most popular way of implementing this process is the chartering of ships. A voyage charter is a type of charter in which a vessel can be hired for a specific voyage, so the charter party must specify ports of call, cargo information, and any restrictions, if any. In most cases, such charters are made when there are stable cargo flows and where payment for such a form of charter can be made using two types, either per ton of cargo transported or in a lump sum. This form of charter operates within the tramp form of shipping. In this case, the charterer can be either the person who owns the cargo or the person who charters the ship at someone else's expense. The so-called "Owner" of the vessel, from whom the charterer of the actual voyage charters the vessel, can himself also be a time charterer or even a voyage charterer, who also sub-charters (sublets) the vessel. If the owner is not a registered owner of the vessel, it is usually described as a "time-charter owner" or a "disponent owner", which effectively indicates the existence of a chain of charter arrangements, which can be treated as separate and distinct. Under a voyage charter, the owner retains operational control of the vessel and is responsible for operating costs such as port fees, bunkering, additional insurance, taxes, etc. At the same time, voyage charter costs and charges are attributable to the cargo. In practical terms, voyage charter means a contract where the owner promises to carry on board a specific vessel a specific cargo from one port to another, undertaking to provide a vessel to arrive at a conditional port of loading and to be ready to receive the cargo on a certain day or within a certain period.

In order to demonstrate the proposed approach, a flowchart has been developed that summarizes the operational logic implemented in the formalization process, Figure 1.

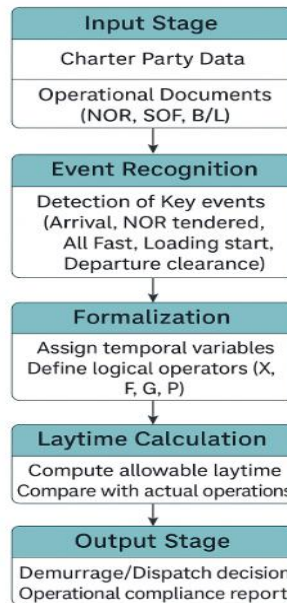


Figure 1: Voyage Flow Diagram

Figure 1 illustrates that the model begins with inputs from contractual and operational documentation, followed by an extraction of key events recorded during the voyage. The process then heads towards the formalization of these events by assigning temporal variables and applying logical operators for accurate calculation of laytime and deviations from contractual time limits. At the last stage, operational conclusions, for example, demurrage or dispatch, are generated, as well as reports on compliance with contractual terms. The presented structured process will generally provide for more transparency, reproducibility, and adaptability of the methodology toward different voyage operation scenarios.

There are certain chartering requirements to information about the vessel's arrival in the port for effective planning and optimal utilization of port facilities, as well as for avoiding vessels' idle time. Moreover, the captain is obliged to submit timely notices of the estimated date and time of the vessel's arrival at the port of loading. Failure to submit such information in time or inaccuracy is subject to an increase in the laytime. Sometimes notices also specify the amount of cargo, which is supposed to be loaded on board. This helps the charterer to prepare the necessary quantity of cargo for shipment and prompt processing of the ship. For commodity cargoes, in spite of the high intensity of ships' handling and the availability of specialized complexes, the probability of idle time waiting for a berth is still high. Therefore, in some charters, the shipowner is warned that waiting time "in the normal queue" is possible at his expense, or the vessel will be handled "in the normal queue in the normal manner". It also stipulates the maximum waiting time in the queue at the shipowner's expense, which enables the shipowner to calculate the demurrage costs attributable to him. The specialization of modern ports and berths makes it possible to determine the intensity of vessel handling with great accuracy when concluding a charter. Special scales of loading rates, differentiated according to the deadweight of the vessel, have been worked out for this purpose. The scales are of a recommendatory character, attached to charters and usually revised annually. Similar scales are worked out for demurrage rates. In the practice of handling ships with shore-side handling equipment, a certain order of attributing the costs of loading, docking and discharging the cargo to the charterer is applied. The special importance of charter terms

about loading and unloading forces requires careful specification, with various clauses, their interpretation.

The process of maritime transportation of goods consists of three main stages: loading, carriage and unloading. The loading stage includes all operations from the moment of introduction of cargo for shipment by sea by the consignor (or from another mode of transport) until the moment of loading it on board the ship and departure from the port. The shipping stage includes all operations related to the movement of cargo from the port of departure to the port of destination, i.e. ship's passage by sea. The unloading stage includes all operations from the moment of the ship's arrival at the port of destination to the moment of cargo transfer to the consignee (or to another type of transport). The process of cargo loading is also a set of technological operations related to the preparation of the vessel to accept the intended cargo and accordingly the subsequent preparation for her departure to the sea, which is determined by the moment of completion of cargo operations and paperwork for the previous voyage before the vessel is ready to leave the port of departure to perform the current voyage. Ship's voyage in loaded condition is a set of technological operations related to departure from the port of origin, passage, and arrival at the port of destination. Cargo unloading is a complex of technological operations related to the preparation of a vessel for the discharge of cargo, the delivery of cargo to the consignee, and the execution of necessary documents related to the completion of the voyage. At the first and the last stages of the transportation process, apart from various production operations, commercial operations are also performed, including the execution of necessary documents and the performance of certain procedures. It is known that the main type of technological process of transport ship operation is a voyage, which is determined by the voyage instructions provided beforehand to the Master. Each voyage of the ship consists of separate work processes. During the voyage, the working processes include:

- ballast passage to the loading port;
- arrival and berthing at the loadport;
- preparation for a laden voyage;
- departure from the port;
- laden voyage (sailing time);
- arrival to the discharging port;
- berthing at the discharging port.

Before and during all these stages certain measures must be meticulously implemented to maintain the safety of the vessel and cargo during the voyage, most of which fall on the master and the ship's crew, Tab.1;

Table 1: Master's rights and duties in preparing the vessel for forthcoming voyage

During the ship passage	While in port
<ul style="list-style-type: none"> • At the beginning and during the voyage, maintain the ship's seaworthiness and monitor the compliance of all mandatory requirements and regulations relating to the cargoes loaded, as contained in international conventions and IMO codes, as well as in the relevant instructions of the shippers. 	<ul style="list-style-type: none"> • Before the voyage, get the vessel in seaworthy condition; bring the holds and other rooms on board in a condition that ensures proper cargo handling and transportation. Ensure the safety of cargo stowage and securing on board, monitor the packaging and marking of the cargo;
<ul style="list-style-type: none"> • Ensure the proper safety of the cargo and take all reasonable measures to protect the cargo from loss, shortage, and theft; 	<ul style="list-style-type: none"> • Confirm the ship's cargo plan, arranged and submitted for approval at the port of loading;

<ul style="list-style-type: none"> • Ensure a sufficient quantity of bunker, food, and fresh water on board the ship; 	<ul style="list-style-type: none"> • Arrange for proper recording of the statement of time and laytime at the port of loading/unloading;
<ul style="list-style-type: none"> • Know the full technical capabilities of the ship to handle cargo, while ensuring the safety of the vessel, crew, and cargo; 	<ul style="list-style-type: none"> • Check the shipping documents, sign the bills of lading, insert the necessary remarks, and submit them to the shipper;
<ul style="list-style-type: none"> • Submit a sea protest to the appropriate authorities at the nearest port of call if the cargo has been damaged or lost for any reason during the voyage; 	<ul style="list-style-type: none"> • Ensure that the ship is loaded following the International Load Line Certificate, provide the ship's records and correspondence with the shipowner, including those related to the commercial matters;

Pre-voyage preparation means not only performance by the carrier, on behalf of which the Master and the crew act, of its obligations under the contract of maritime carriage, but also creation of necessary conditions for the implementation of international legal standards of shipping in the course of carriage. During preparation of the vessel for the voyage, the necessary grounds should be laid with respect to the condition of the vessel, cargo, crew proficiency for the implementation during the whole voyage a set of national and international rules of shipping, which ensure normal and safe operation of the vessel with people and cargo on board.

Planning of forthcoming voyage is quite responsible procedure, which requires collection of certain amount of information, including full description of sailing conditions, ports of call and forthcoming voyage details related to loading and unloading operations, which require careful consideration of time. Thus, the voyage of the ship involves precise calculations to determine all the physical and temporal characteristics to achieve a positive result.

On behalf of the shipowner, the agent serving the ship is obliged to pay, at the ship's expense, the officially established charges for the given port, as well as the services and work performed on the Master's order. Based on the invoices issued for the services performed, the ship's agent draws up a consolidated invoice, which is commonly referred to as a disbursement invoice. This invoice shall be submitted by the agent for payment to the ship owner. Disbursement invoice shall be in good faith and substantiated with supporting documentation for each charge, for each service.

Figure 2 shows the structure of port costs incurred in the process of servicing a ship in the port. The main cost items are shown, including port dues, mooring costs, agency services, loading and unloading, and administrative fees.

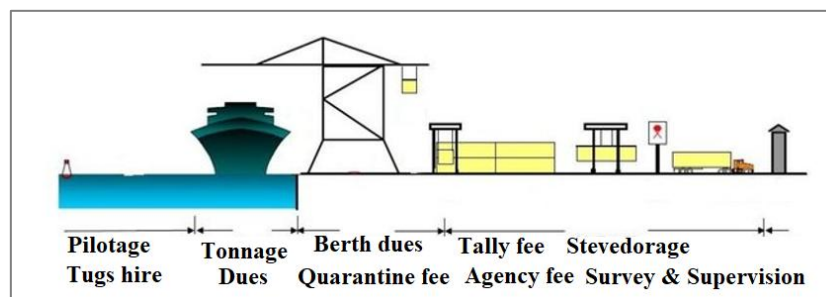


Figure 2: Port Disbursement Charges

A clear understanding of the composition of port costs allows the shipowner to effectively plan financial expenses during the vessel's berthing and optimize interaction with agents. Systematization of costs is also the basis for further analysis of the efficiency

of ship handling in ports and assessment of the impact of berthing on the overall costs of the voyage.

Practice of ship's arrival and departure formalities in ports of different countries slightly differs. However, the Convention on Facilitation of International Maritime Traffic was adopted to simplify the process of vessel's arrival/departure formalities and unify the forms of transport documents. The process of ship's arrival to port is the fulfillment of all port formalities and operations necessary for obtaining permission or free pratique in a given port. Appointed ship's agent executes all necessary documents where the end of such process is considered the moment of handing over to the Master of the "Port clearance" for the next port of call.

The Figure 3 schematically shows the ship's document flow and interaction with various parties in the port, from arrival to departure. The main stages of clearance are included: submission of preliminary notifications, passing through control, obtaining permits for operations, and completion of port formalities.

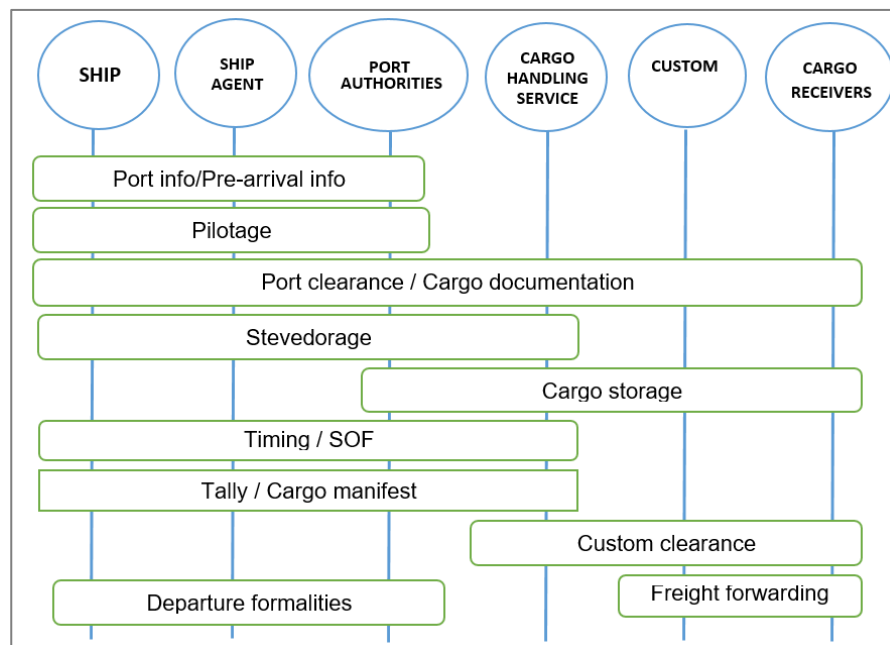


Figure 3: Port Turnover Cycle And Paperwork With The Parties Concerned

Visualizing the document flow cycle presented in Figure 3 allows better planning of formalities, reducing the risk of delays. Timely document preparation and coordination with port services directly affect the duration of the vessel's stay in the port and the calculation of the berthing time.

The vessel obtains free practice permission for shore communication and cargo operations once the formalities are settled with the port authorities. After the necessary inspections are made and permits are issued, the vessel can commence operations: loading/unloading cargo, receiving supplies, and changing crew members. It is in the interest of the ship (shipowner) and the port authorities that formalities related to the ship's arrival, departure and time in port should be completed as soon as possible, while ensuring reliable supervision over the rules, requirements and regulations in force on the ship. The time a ship in port must often be used as advantageously as possible by the shipowner to conduct the numerous operations necessary to ensure the ship's operation.

Figure 4 shows the shipowner's network of business relations with the main participants in the maritime transportation process: charterers, agents, insurance companies, cargo owners, and other contractors.

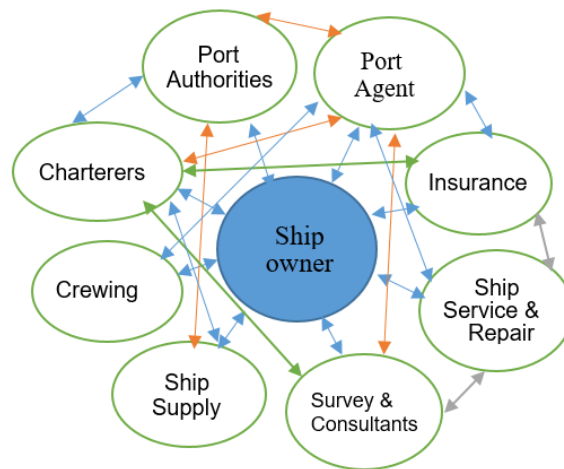


Figure 4: Shipowner’s Business Relationship Network

Understanding the structure of the shipowner's business interaction is essential for properly managing commercial risks and organizing operational support for the voyage. Well-established interaction with all participants helps to minimize delays related to cargo handling, paperwork and coordination of procedures in the port.

The duration of a ship's berthing in the port depends first on the quantity of cargo that a ship accepts and on the intensity of cargo operations, i.e. on the rate of cargo loading performance. It also depends on the time spent for additional operations related to the ship's service in port, berthing of the ship, preparation of holds, execution of cargo documents, bunkering (if, for technical reasons, fuel cannot be accepted during cargo operations), shifting of the ship in port, etc. Finally, the actual duration of a vessel's berthing time in port includes any idle time due to meteorological reasons and non-productive berths (waiting for berth, cargo, manpower, tugs, failure of machinery, waiting for orders, etc.).

To ensure consistency and facilitate interpretation of the formalization, all symbols used in the proposed model are defined in Table 2. The table lists the notation, a brief description, and measurement units (where applicable) for each variable. This systematic reference allows the reader to navigate the mathematical framework without ambiguity and supports reproducibility.

Table 2: Variable Reference Table

Symbol	Description	Units
t_{NOR}	Time of Notice of Readiness tendered	DateTime
t_{AF}	Time of “All Fast” (mooring completed)	DateTime
t_{LS}	Time of loading start	DateTime
t_{LE}	Time of loading end	DateTime
t_{DS}	Time of discharging start	DateTime
t_{DE}	Time of discharging end	DateTime
L_{max}	Maximum allowed laytime according to Charter Party	hours
L_{act}	Actual laytime used	hours

fp	Free pratique clearance event (1 = granted, 0 = not granted)	Boolean
W_{wt}	Weather working time (time excluded due to weather conditions)	hours
D	Demurrage (monetary penalty for exceeding laytime)	USD
P	Dispatch (bonus for saving laytime)	USD
ΔL	Laytime deviation ($L_{act} - L_{max}$)	hours
E	Event set used in temporal logic formalization	-
X, F, G, P	Temporal logic operators: Next, Eventually, Globally, Previously	-

The symbols listed in Table 2 cover the primary temporal and operational variables employed in the model. They are consistently applied throughout the formalization to describe key events, contractual constraints, and financial outcomes. The standardization of notation contributes to the clarity of the logical expressions and supports their potential integration into automated decision-support systems for maritime operations.

3. Results of the Formalization

A tramp vessel voyage is a production cycle of the vessel's operation, which must be performed (under all other conditions) as specified in the voyage charter party (C/P). Each part of the voyage is confirmed and reconciled with the issued documents confirming its commencement and completion. Causal relationships between parts of the voyage and required documents can be formalized with the help of temporal logic operators.

Signed charter party (C/P) initiates the vessels voyage and it can be formulated with the terms of temporal operators P (PAST) and F (FUTURE):

$$P\left(t_{c/p} \wedge Fp_v\right), \quad (1)$$

where $t_{c/p}$ - the time point of C/P signing; p_v - the voyage itself as a process.

The voyage probably is the complex process that consists from the several sub-processes that is to say on ballast passage (if any) p_b , loading stage p_l , enroute p_r and discharging stage p_d that logically follows each other as it show below using X (NEXT TIME) and G (GLOBALLY) operators

$$P\left(p_b \wedge XFp_l\right) \Rightarrow P\left(p_l \wedge XFp_r\right) \Rightarrow P\left(p_r \wedge XFp_d\right), \quad (2)$$

and

$$G\left[\neg\left(p_b \wedge p_l \wedge p_r \wedge p_d\right)\right]. \quad (3)$$

The ballast passage of the ship to the loading port starts from the moment of receiving the voyage instructions from the charterer with the shipowner's approval and lasts until the ship's actual arrival to the loading port. The vessel's arrival shall be considered to have occurred at the moment the vessel crosses the port boundaries, as soon as the Master has submitted a notice of readiness:

$$P(t_{CP} \wedge Fp_b) \wedge p_b = [t_{VI}; t_{AN}], \quad (4)$$

Where t_{VI} - the time point of receiving the voyage instructions; t_{AN} - the time point of tendering the arrival notice for port of loading.

The ballast passage is the sub-process on the whole voyage, during which the Master should tender to the parties involved in the Estimated Time of Arrival notice. It declares the date and time of the expected ship's arrival to the load port:

$$t_{VI} | = p_b \cup p_l \equiv (\exists t_{AN} \geq t_{VI}):$$

$$\left(t_{AN} | = p_l \wedge \left(\forall t_{ETA} : t_{VI} \leq t_{ETA} \prec t_{AN} \right) : t_{ETA} | = p_l \right) \quad (5)$$

where t_{ETA} - time point of tendering the ETA notice.

It should be noted that parties may agree on several ETA notices, so formally speaking, a charter party may oblige a shipowner to notify ETA on a regular basis or at the time of passing geographical points. Normally during a ballast passage notification must be given at various intervals with a final notification when the ship actually arrives:

$$t_{ETA} \rightarrow t_{AN} \quad (6)$$

The vessel's time in port is one of the most essential parts of the voyage time, considering that the voyage itself is for cargo transportation. In contrast, shipping of cargo is not possible without the processes of loading and unloading. The duration of cargo handling operations constitutes most of the vessel's time in port, but there are some stages connected with paperwork that must take place before and after cargo loading/unloading and are of key importance in recording time in port.

From the moment of the ship's arrival at a port, the port time period, also known as pre-shipment time, begins. According to domestic legislation and local rules, the vessel's arrival must be documented with various authorities, government controls, and other relevant entities, depending on the type of cargo to be loaded or unloaded. Therefore, this pre-loading stage heavily relies on the activities of the ship agent at the port. As soon as they receive the nomination and ETA notifications, they must organize and execute the relevant procedures to ensure that the ship's arrival at the port is documented immediately upon physical arrival. Also, another crucial aspect is to coordinate and approve the proposed cargo plan, which must be developed during the preliminary loading stage. However, this coordination does not initiate the next phase - the actual loading; without a drafted preliminary cargo plan, loading the cargo into the ship's holds is impossible. The fundamental document that records the loading process from start to finish is the SOF (Statement of Facts). After loading, the ship must also obtain departure permission from the port, likely following the same procedures as for arrival and involving the same authorities. Thus, the loading process can be represented as comprising the time before loading, the loading itself, and the time afterward.

$$G\left[\neg\left(p_{pre-l} \wedge p_l \wedge p_{post-l}\right)\right] \quad (7)$$

and

$$P\left(p_{pre-l} \wedge XFP_l\right) \Rightarrow P\left(p_l \wedge XFP_{post-l}\right) \quad (8)$$

The document establishing the beginning of the pre-shipment period is the final notice of arrival and the Notice of Readiness, and it is at this point that the ship's agent must provide free pratique after all required formalities. The time of the actual commencement of loading is specified in the SOF. Documentation of the preparatory stage of loading begins with the notification of arrival and ends with the point in time in the Statement of Facts that records the beginning of loading:

$$p_{pre-l} = \left[t_{AN}; t_{SOF} \right] \quad (9)$$

t_{SOF} - the point of time in SOF that indicates the actual moment of the beginning of loading. Probably SOF indicates also some pre-loading operations like berthing, port clearance etc. However, in the context of this article, a document records the beginning of the cargo loading process, so we use it as a record that marks the beginning of loading with the appropriate time point.

$$\begin{aligned} t_{AN} \Big|_{=} p_{pre-l} \cup p_l &\equiv (\exists t_{SOF} \geq t_{AN}): \\ (t_{SOF} \Big|_{=} p_l \wedge (\forall t': t_{AN} \leq t' < t_{SOF})) &: t' \Big|_{=} p_l \end{aligned} \quad (10)$$

subject to

$$t' \equiv t_{NOR} < t_{pcl} \because W_{wt} \otimes t' \equiv t_{pcl} < t_{NOR} \because fp \quad (11)$$

and

$$t_{AN} \rightarrow t_{NOR} \otimes G\left[t_{pcl} \Rightarrow Ft_{NOR}\right] \quad (12)$$

Tendering the Notice of Readiness (NOR) is the main point in the cargo loading process, fixing the fact of the vessel's readiness and launching the laytime calculations. So the time moment of its tendering depends on the CP terms, as it is considered in (12) and (13), but there is also a grace period between the NOR is tendered/accepted and the physical commencement of the loading operations. Usually, the duration of this grace period is not very long, that is why

$$t_{NOR} \rightarrow t_{SOF} . \quad (13)$$

The time window for cargo is a quite strong clause in a charter agreement (technically speaking, the charterer can cancel it if the ship is late), so the NOR must be filed no later than the cancellation date expires:

$$t_{NOR} \in [t_{ld}; t_{can}], \quad (14)$$

where t_{ld} and t_{can} - laydays and cancelling dates respectively according to the CP.

Probably, the NOR time point can be up to laydays - and if so, given that the charterer has the possibility and willingness to do so, the ship can be berthing for loading. However, we study and formalize the situation based on already signed CP, without taking into account possible (and, by the way, quite often happens) deviation from it. Nevertheless, just SOF as a document indicates the beginning of loading, so

$$P(p_b \wedge Fp_l) \wedge p_l = [t_{SOF}; t_{BL}], \quad (15)$$

where t_{BL} - the time point of the BL (Bill of lading) signing.

After signing the BL some time should be taken to obtain permission to leave the port, port clearance and the beginning of the post-loading period of the voyage, the duration of which is fixed with the points of time

$$P_{post-l} = [t_{BL}; t_{DN}], \quad (16)$$

where t_{DN} - time of tendering the departure notice.

Such post-loading period in fact is the period of obtaining the port clearance for departure. Nevertheless, considering the short duration of the procedure and formalities between the loading completion and the receiving the port clearance we assume

$$t_{BL} \rightarrow t'_{pc}, \quad (17)$$

where t'_{pc} - the time point of departure permission (port clearance), and it is the time of the notice of departure, which indicates the time of the beginning of the ship's passage to the discharging port, then

$$t'_{pc} \rightarrow t_{DN}, \quad (18)$$

where t_{DN} - the time point of tendering the notice of departure.

The next voyage stage is the ship's passage to the port of discharging:

$$P(p_l \wedge Fp_r) \wedge p_r = [t_{DN}; t_{AN'}], \quad (19)$$

where $t_{AN'}$ - the time point of tendering arrival notice for port of discharging.

$$t_{DN} \Big| = p_l \cup p_r \equiv (\exists t_{AN'} \geq t_{DN}):$$

$$\left(t_{AN'} \Big| = p_l \wedge \left(\forall t_{ETA'} : t_{DN} \leq t_{ETA'} \prec t_{AN'} \right) : t_{ETA'} \Big| = p_r \right), \quad (20)$$

where $t_{AN'}$ - time point of the tendering of the arrival notice to the port of discharging; $t_{ETA'}$ - time point of tendering the ETA notice for port of discharging.

In the documentary, the vessel's arrival at the port of discharging is the same as her arrival at the port of loading, at least regarding the tendering of NOR, getting of port clearance, and fixing of discharging time duration in SOF. Apparently, here we have the same three stages as described in the port of loading: pre-discharging, actual discharging, and post-discharging.

$$G \left[\neg \left(p_{pre-d} \wedge p_d \wedge p_{post-d} \right) \right] \quad (21)$$

and

$$P \left(p_{pre-d} \wedge X F p_d \right) \Rightarrow P \left(p_d \wedge X F p_{post-d} \right) \quad (22)$$

where pre-discharging stage is the same to the loading stage - the vessel should be berthed, obtain port clearance and tendering NOR (last two may change in time with each other depending on the CP terms. So pre-discharging stage starts from the moment t of vessels arrival to the discharging port and ends at the moment that stated in SOF as the beginning of discharging:

$$p_{pre-d} = \left[t_{AN'} ; t_{SOF'} \right] \quad (23)$$

$t_{SOF'}$ - the point of time in SOF that indicates the actual moment of the beginning of discharging.

$$t_{AN'} \Big| = p_{pre-d} \cup p_d \equiv (\exists t_{SOF'} \geq t_{AN'}):$$

$$\left(t_{SOF'} \Big| = p_d \wedge \left(\forall t'' : t_{AN'} \leq t'' \prec t_{SOF'} \right) \right) : t'' \Big| = p_d \quad (24)$$

subject to

$$t'' \equiv t_{NOR'} < t_{p_{dcl}} \quad \dots \dots W_{wt} \otimes t'' \equiv t_{p_{dcl}} < t_{NOR'} \quad \dots \dots f_p \quad (25)$$

and

$${}^tAN' \rightarrow {}^tNOR' \otimes G\left[{}^t_{p_{dcl}} \Rightarrow Ft_{NOR'}\right] \quad (26)$$

The same to the loading, the point that fixes the beginning of discharging is indicated in SOF' and the finishing of discharging is approved by signing for example the survey draft report in the case of assuming bulk cargoes carriage or final tally report with general cargoes, then

$$P\left(p_r \wedge Fp_d\right) \wedge p_d = \left[{}^t_{SOF'}; {}^t_{SR}\right], \quad (27)$$

where ${}^t_{SOF'}$ - the point of time in SOF' that indicates the actual moment of the beginning of discharging; ${}^t_{SR}$ - the time point of signing of draft survey report and

$$G\left[{}^t_d^e \Rightarrow Ft_{SR}\right] \quad (28)$$

Thus, the signing of the final draft survey report or final tally report by the Master is obviously the starting point for the post-discharge phase, which includes actions and documents for obtaining port permission. This stage culminates in the submission of departure notice.

It is of great importance to establish rules determining the procedure for calculating the ship's dock time and the obligations incumbent upon the shipowner, shipper and charterer during the ship loading and unloading time. The port regulations governing these relations shall apply in cases where the ocean freight contract does not contain the relevant instructions concerning the matter governed by the regulations. In these cases, the application of the applicable rule established by the port can take place either on the basis of the condition on the application of the port habits contained in the ocean freight contract or due to the fact that the rule of law to be applied in resolving the issue arising in the relationship between the parties refers to the port customs.

In order to verify the performance of the proposed logical model, an application test was conducted based on conditional real operational data from the port of Constanta (Romania) for a 50,000 dwt dry cargo vessel. The charter conditions provided for 48 hours of laytime and the possibility of submitting NORs according to the WIBON principle.

The data was obtained from the standard templates of the Statement of Facts and Notice of Readiness, adapted for a scientific publication. This example allows you to recreate the sequence of events in the port, calculate the actual loading time, determine the excess of laytime and calculate the potential demurrage (Table 3).

Table 3: Chronology of events (Statement of Facts)

Event	Date & Time
Vessel enters port area	10 June, 08:00
NOR tendered	10 June, 09:00
All Fast alongside	10 June, 10:30

Loading commenced (SOF)	10 June, 11:00
Loading completed	12 June, 15:00
Bill of Lading signed	12 June, 16:00
Departure clearance granted	12 June, 17:00
Vessel departed	12 June, 18:00

According to the terms of the charter, the laytime started from the moment the NOR was accepted - June 10 at 09:00 and ended on June 12 at 09:00. The actual loading lasted from 11:00 on June 10 to 15:00 on June 12, i.e. 52 hours. This is 4 hours more than the established limit, which, according to the terms of the C/P, forms the basis for charging demurrage.

The sequence of key events can be represented using temporal logic operators:

Let:

$t_{NOR} = 10 \text{ June, } 09:00;$

$t_{LS} = 10 \text{ June, } 11:00 \text{ (loading start);}$

$t_{LE} = 12 \text{ June, } 15:00 \text{ (loading end);}$

$L_{max} = 48 \text{ h (laytime allowance).}$

Then:

1. Event ordering

$$t_{NOR} \xrightarrow{x} t_{LS} \xrightarrow{x} t_{LE} . \quad (29)$$

2. Laytime condition

$$t_{LE} - t_{NOR} > L_{max} \Rightarrow \text{Demurrage applies} . \quad (30)$$

3. Temporal operators usage: $NOR \rightarrow \diamond$ Loading Start (F: “in the future”), Loading Start $\rightarrow \diamond$ Loading End; If $t_{LE} > t_{NOR} + L_{max}$, trigger demurrage clause.

This example demonstrates the ability of the proposed logical model to reproduce the time sequence of port operations in accordance with the actual data and terms of the charter agreement. The formalization of key events using temporal operators ensures the correct calculation of the used laytime, as well as the identification of exceeding the established time limits, which is directly relevant for determining the financial consequences (demurrage or dispatch). The use of operational data as close as possible to real-world data increases the validity of the methodology and confirms its applicability in the practical analysis of commercial risks in the field of maritime transportation.

4. Discussion

In this case, formalizing the stages of a vessel's voyage using temporal logic operators proved valuable for structured analysis of the vessel's time obligations under a voyage charter. By modeling the sequence of all stages of the vessel's operation from receiving instructions to completing unloading in a formal time space, the study provides a clear analytical framework for strategic planning and resolving disputes in maritime logistics.

The modeling confirms that each legally significant or operational action during the voyage has a clear time-space anchoring, which can be reflected through logical operators

such as *X* (next action), *G* (always), *F* (in the future), *P* (in the past). This allows us to model the entire route under various scenarios and identify critical points of possible delays or legal disputes in advance.

The practical value of formal logic is manifested in the following aspects:

- identify conflicts between contractual terms and conditions regarding leitmotif and the actual course of events;
- evaluation of the impact of delays before loading or after unloading on the total charter costs;
- structuring automated decision support systems for voyage planning and port interaction.

Documents such as Statement of Facts (SOF) and Notice of Readiness (NOR) play a key role in the model. They serve as time "anchors" for the transition between logical states. This provides a quantitative assessment of the start and end of the lifetime, which is critical for calculating fines or bonuses (demurrage/dispatch).

Given the digital transformation of shipping - the introduction of electronic bills of lading, smart contracts, digital voyage planning - the proposed formalization can become the basis for automated charter analysis and risk assessment systems useful for shipowners, charterers and maritime lawyers.

In further research, this approach can be extended to probabilistic risk modeling (weather conditions, port congestion), and integrated into simulation environments for maritime decision support systems. This will help reduce the frequency of disputes and increase the transparency of voyage chartering conditions.

4. Conclusion

This study proposes a formalized approach to modeling the stages of a ship's voyage using temporal logic, which allows describing maritime transport operations as a sequence of logically interrelated events in time. This approach makes it possible not only to reproduce the temporal structure of the voyage cycle, but also to formalize the conditions under which certain legal consequences come into force (for example, the start of laytime, accrual of demurrage).

The developed model integrates the key events recorded in the voyage documentation (Notice of Readiness, Statement of Facts, Bill of Lading) and establishes clear logical rules for transitions between operational states. Particular attention is paid to aligning the formalized rules with the actual performance of operations, which creates the basis for the development of automated systems for verifying compliance with contractual terms in real time. The revised version of the paper presents an example case based on operational data as close as possible to real-world data, which illustrates the applicability of the model and confirms its ability to provide accurate laytime calculations and detect deviations from contractual restrictions.

The results of the study can be applied in practice to model scenarios of legal liability of the parties, verify timesheets, and assess the degree of deviation from the optimal schedule. The proposed formalization also has the potential to be integrated with risk analysis and simulation modeling methods, including agent-based approaches. Prospects for further research include extending the methodology to multi-port routes, using stochastic risk assessment, and creating intelligent decision support systems for voyage planning, optimizing operations, and ensuring legal transparency in the field of maritime transportation.

References

Akarachotikavanith, W. (2015) "Legal problems on demurrage in voyage charters", Master thesis on Laws Program in Business Laws, Faculty of law, Thammasat University, Thailand.

Basok, B. I., Baseyev, Y. T., Kostogryz, K. P., & Iliencko, B. K. (2024) "Hydrogen power and not only: Pro and contra", *Energotehnologii i Resursosberezenie*, 79(2), 110-125.

Bastug, S., Deveci, D., Yıldırım, C. (2016) "The usage of information sources in chartering of ships by charterers", In Conference: 14th International Logistics and Supply Chain Congress. İzmir, Türkiye, 409-422.

Batrinca, G. (2007) "E-Chartering Web Based Platforms Between Success and Failure", Conference: 7 th International symposium on marine navigation and safety of sea transportation, Trans-NavAt: Gdynia, Poland.

Beullens, P., Ge, F., & Hudson, D. (2023). "The economic ship speed under time charter contract - A cash flow approach", *Transportation Research Part E: Logistics and Transportation Review*, 170, 102996.

Boviatsis, M. (2022). "Legal assessment of BIMCO's infectious or contagious diseases (IOCD) clauses for voyage and time charter parties", *Marine Policy*, 144, 105206.

Branski, R., Jesus, M. (2021) "Pricing model for FPSO chartering", *Brazilian Journal of Petroleum and Gas*, 15, 53-60.

Budashko, V., Obniavko, T., Onishchenko, O., Dovidenko, Y., Ungarov, D. (2020) "Main Problems of Creating Energy-efficient Positioning Systems for Multipurpose Sea Vessels", 2020 IEEE 6th International Conference on Methods and Systems of Navigation and Motion Control, MSNMC 2020 - Proceedings, art. no. 9255514, 106-109.

Cariou, P., Wolff, F-C. (2013) "Chartering practices in liner shipping", *Maritime Policy & Management*, 40.

Cernisevs, O.; Popova, Y.; Cernisevs, D. "Risk-based approach for selecting company key performance indicator in an example of financial services". *Informatics 2023*, 10, 54.

Chen, J.; Hong, Z.; Beihua, Z. "Improved vessel allocation model of liner shipping and its application for slot chartering under shipping alliance". *J. Transp. Syst. Eng. Inf. Technol.* 2008, 8, 120-125.

Drozshzyn, O.; Koskina, Y. "The model of container feeder line organization focused on the nature and parameters of external container flows". *Commun. Sci. Lett. Univ. Žilina* 2021, 23, A94-A102.

Fomin, O.; Gerlici, J.; Vatulia, G.; Lovska, A.; Kravchenko, K. "Determination of the loading of a flat rack container during operating modes". *Appl. Sci.* 2021, 11, 7623.

Fomin, O.; Vatulia, G.; Lovska, A.; Gerlici, J.; Kravchenko, K. "Stability study of tank containers placed on a roll-trailer during transportation by railway ferry". *TransNav* 2021, 15, 311-315.

Georgoudakis, D.; Sys, C.; Hassel, E.V.; Syriopoulos, T. "Evaluating the impact of energy efficiency on time charter rates of containerships". *Transp. Res. D Transp. Environ.* 2025, 139, 104590.

Golikov, V.A.; Golikov, V.V.; Volyanskaya, Y.; Mazur, O.; Onishchenko, O. "A simple technique for identifying vessel model parameters". *IOP Conf. Ser. Earth Environ. Sci.* 2018, 172, 012010.

Hayashi, K. “Determining shipping cycle by supply/demand ratio and Markov regime switching”. In Proceedings of the IAME (International Association for Maritime Economists) Conference, Busan, Republic of Korea, 2022.

Holliday, S. “Port and shipping management practice: Role of the oil industry and charterers”. *Mar. Policy* 1993, 17, 387-390.

Kazarezov, A.Y.; Gal, Y. “Commercial work on the sea transport: logistics aspect: a training manual”. NUK: Mykolaiv, Ukraine, 2020; 248 p.

Kiseleva, E.; Stepanets, V.; Pilyugin, A.; Valkova, S. “Hierarchical representation of decision-making in chartering a vessel on a voyage charter”. *IOP Conf. Ser. Earth Environ. Sci.* 2022, 988, 022041.

Koskina, Y.; Onyshenko, S.; Drozhzhyn, O.; Melnyk, O. “Efficiency of tramp fleet operating under the contracts of affreightment”. *Sci. J. Silesian Univ. Technol. Ser. Transp.* 2023, 120, 137-149.

Kurennov, S.; Smetankina, N.; Pavlikov, V.; Dvoretzkaya, D.; Radchenko, V. “Mathematical model of the stress state of the antenna radome joint with the load-bearing edging of the skin cutout”. *Lect. Notes Netw. Syst.* 2022, 305, 287-295.

Kurennov, S.; Smetankina, N. “Stress-strain state of a double lap joint of circular form. Axisymmetric model”. *Lect. Notes Netw. Syst.* 2022, 367, 36-46.

Lapkina, I.; Malaksiano, M.; Malaksiano, M. “Optimization of the structure of sea port equipment fleet under unbalanced load”. *Actual Probl. Econ.* 2016, 183, 364-371.

Malaksiano, N. “On the stability of economic indicators of complex port equipment usage”. *Actual Probl. Econ.* 2012, 138, 226-233.

Mazioli, F. C., Rosa, R. D. A., Sagrilo, R. G. V., Vitorugo, L. R., & Neves, B. D. S. (2019). “Assessment of the impact of Charter Party clauses and port’s characteristics on the port’s financial result”, *Computers & Industrial Engineering*, 128, 70-90.

Melnyk, O., Onyshchenko, S., Onishchenko, O., Koskina, Y., Lohinov, O., Veretennik, O., & Stukalenko, O. (2024) “Fundamental concepts of deck cargo handling and transportation safety”, *European Transport - Trasporti Europei*, 98.

Melnyk, O.; Onyshchenko, S.; Koryakin, K. “Nature and origin of major security concerns and potential threats to the shipping industry”. *Sci. J. Silesian Univ. Technol. Ser. Transp.* 2021, 113, 145-153.

Melnyk, O.; Malaksiano, M. “Effectiveness assessment of non-specialized vessel acquisition and operation projects, considering their suitability for oversized cargo transportation”. *Trans. Marit. Sci.* 2020, 9, 23-34.

Melnyk, O.; Bychkovsky, Y.; Onishchenko, O.; Onyshchenko, S.; Volianska, Y. “Development the method of shipboard operations risk assessment quality evaluation based on experts review”. *Stud. Syst. Decis. Control* 2023, 481, 695-710.

Melnyk, O.; Onyshchenko, S.; Onishchenko, O.; Shcherbina, O.; Vasalatii, N. “Simulation-based method for predicting changes in the ship's seaworthy condition under impact of various factors”. *Stud. Syst. Decis. Control* 2023, 481, 653-664.

Nagurney, A.; Pour, I.; Kormych, B. “Integrated crop and cargo war risk insurance: Application to Ukraine”. *Int. Trans. Oper. Res.* 2024, in press.

Nikitakos, N.; Lambrou, M. “Digital shipping: The Greek experience”. *Res. Transp. Econ.* 2007, 21, 383-417.

Nokkala, M.; et al. “Summary report on the costs of extreme weather for the European transport system”. *VTT Tech. Res. Cent. Finl.* 2012; 98 p.

Onishchenko, O.; Shumilova, K.; Volyanskyy, S.; Volyanskaya, Y.; Volianskyi, Y. “Ensuring cyber resilience of ship information systems”. *TransNav* 2022, 16, 43-50.

Onyshchenko, S.; Koskina, Y.; Savelieva, I. “Developing a logit model for the provision of the process of managing the conclusion of voyage chartering transactions”. *East.-Eur. J. Enterp. Technol.* 2016, 6, 26-31.

Onyshchenko, S.; Melnyk, O. “Probabilistic assessment method of hydrometeorological conditions and their impact on the efficiency of ship operation”. *J. Eng. Sci. Technol. Rev.* 2021, 14, 132-136.

Plomaritou, E.; Jeropoulos, S. “The digitalisation in chartering business: Special reference to the role of e-bill of lading in the bulk and liner markets”. *J. Shipp. Trade* 2022, 7, 28.

Plomaritou, E.; Nikolaidis, E. “Commercial risks arising from chartering vessels”. *J. Shipp. Ocean Eng.* 2016, 6, 261-268.

Popova, Y.; Popovs, S. “Effects and externalities of smart governance”. *Smart Cities* 2023, 6, 1109-1131.

Sayed, M.; Akter, M. “An overview of ship brokering and chartering and its challenges in Bangladesh”. *ZENITH Int. J. Multidiscip. Res.* 2022, 12(05).

Sherstyuk, O.; Olekh, T.; Kolesnikova, K. “The research on role differentiation as a method of forming the project team”. *East.-Eur. J. Enterp. Technol.* 2016, 2, 63-68.

Shestopalov, K.O.; Khliyeva, O.Ya.; Ierin, V.O.; Konstantinov, O.I.; Kozminykh, M.N.; Stukalenko, O.M. “Analysis of the energy efficiency of technical solutions of the heat-driven ship ejector refrigeration machine for obtaining sub-zero temperatures”. *Energotehnol. Resursosberez.* 2024, 80, 108-118.

Shin, S.-H.; Lee, P.; Lee, S.-W. “Lessons from bankruptcy of Hanjin Shipping Company in chartering”. *Marit. Policy Manag.* 2019, 46, 136-155.

Shumylo, O.; Yarovenko, V.; Malaksiano, M.; Melnyk, O. “Comprehensive assessment of hull geometry influence of a modernized ship on maneuvering performance and propulsion system parameters”. *Pomorstvo* 2023, 37, 314-325.

Tan, Z.; Li, H.; Wang, H.; Qian, Q. “Maritime container shipping fleet deployment considering demand uncertainty”. *Asia-Pac. J. Oper. Res.* 2021, 38.

Taylor, A. “Chartering strategies for shipping companies”. *Omega* 1982, 10, 25-33.

Turoń, K.; Czech, P.; Tóth, J. “Safety and security aspects in shared mobility systems”. *Sci. J. Silesian Univ. Technol. Ser. Transp.* 2019, 104, 169-175.

Wilmsmeier, G. “Infrastructure charges: creating incentives to improve environmental performance”. *FAL Bull.* 2012, 309.

Zhikharieva, V. “Benchmarking of intangible assets in the shipping industry”. *Trans. Marit. Sci.* 2025, 14, w04.