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# INTEGRATED RISK ASSESSMENT FRAMEWORK FOR NON-COMPLIANCE WITH LINER SHIPPING SCHEDULES

**Summary.** The article discusses the problem of assessing the risks of non-compliance with liner shipping schedules, which is a key factor in the efficiency and reliability of international trade. Given the complexity and diversity of factors affecting schedule disruptions, ranging from port congestion and terminal productivity to the disruptive impact of external force majeure accidents (pandemics, storms, hurricanes, wars, etc.). The study proposes a methodology based on formal conceptual analysis (FCA). This approach allows for a structural risk assessment by grouping factors according to liner service ports of call, assigning weights to them, and calculating their integrated impact on the overall reliability of the schedule. The proposed approach is illustrated with a numerical model that demonstrates how changes in weighting factors can affect the final risk assessment. The results contribute to the development of theoretical approaches to

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risk management in shipping, while offering practical tools for reducing schedule disruptions in the LS-industry.

**Keywords:** liner shipping, shipping schedule, risk

## 1. INTRODUCTION

The Liner Shipping (LS) plays an important role in the development of the global economy, ensuring stable unit-flows of goods between regions. Its efficiency and sustainability directly affect the functioning of international supply chains, the competitiveness of national economies, and the dynamics of global trade. In this context, LS is of particular importance, since it is characterized by the operation of vessels according to predetermined routes and announced schedules. The presence of such schedules forms a key distinguishing feature of liner services and acts as a guarantee of stability and predictability for all participants in the logistics chain.

Nevertheless, ensuring strict compliance with schedules remains one of the most challenging tasks of maritime transport management. Even though schedules are planned with the consideration of numerous operational and commercial parameters, in practice, they are subject to constant risks and uncertainties. Deviations may be caused by a wide range of different factors: from organizational errors and technological failures in ports and sea to weather conditions or global crises, Any delay, regardless of its origin, disrupts the integrity of transport processes, leads to additional costs, reduces the overall reliability of liner transport, and ultimately disrupts the integrity of intermodal delivery.

In modern conditions, where the volume of liner trade is steadily increasing, and the requirements for timely delivery are constantly tightening, the problem of schedule non-compliance acquires particular urgency. For cargo-shippers, adhering to the schedule means fulfilling contractual obligations and maintaining supply chain stability. For LS- companies, this is directly linked to their business reputation, competitiveness, and financial stability. In its turn, for ports and logistics operators, the reliability of logistics companies' schedules determines the efficiency of terminal processes, the level of infrastructure utilization and cargo owners’ satisfaction

Traditional approaches to the analysis of disruptions in LS often focus on identifying separate causes of delays. However, such a fractal consideration does not let for full assessment of the potential for deviations from the schedule. What is needed is a clear and convenient method that integrates multiple factors, reflects their interrelationships, and provides a quantitative assessment of the overall level of risk. The development and application of such methodological tools is an important step in improving the resilience of maritime transport and strengthening its role in global intermodal delivery networks.

The aim of this study is to propose a methodology for assessing the risk of non-compliance with liner schedules that allows for the structured analysis of influencing factors, determination of their relative significance, and calculation of an integral risk indicator. The presented approach is designed to help carriers and logistics operators not only to identify critical areas of vulnerability but also to develop effective management measures aimed at minimizing the consequences of potential disruptions. By doing so, it contributes to increasing the stability and efficiency of LS- operations, which is of both theoretical and practical significance for the liner industry.

## 2. RELATED LITERATURE

The term “liner shipping” is inextricably linked to the concept of “schedule”. In definitions of LS, the existence of a schedule can be presented directly or indirectly: “fixed service,” “regular intervals,” “named ports,” “sailing dates”. The connection between “liner shipping-schedule” is further confirmed by the contrast between LS and tramp shipping, as “non-regular” and “unscheduled”.

The study of risks associated with the LS-industry is a multidisciplinary problem, and the risks of schedule non-compliance are only part of it. Thus, D. Waters [1] identifies 21 types of risks (strategic, natural, political, economic, physical, supply, market, transport, products, operations, financial, information, organization, management, planning, human, technical, criminal, safety, environment, local permits). T. Notteboom [2] draws attention to the importance of high commercial and operational risks associated with the deployment of fixed fleet capacity within a fixed schedule between a set of ports of call at both ends of the trade route. The significant impact of risks and the high probability of delays force liner carriers to include the following remarks next to their schedules: “Above schedule subject to change with or without prior notice”, "All information given above is only for indicative and commercial purposes and cannot be considered as a contractual commitment from ... line” and similar notes.

Among the main risks studied in the literature in the context of the threat of delays and non-compliance with the liner schedule are: port congestion [3], terminal productivity [4], seasonal fluctuations in transportation demand [5], empty container management [6], fleet and container equipment availability [7], corruption/inefficiency of port authorities and regulatory agencies [8], fuel prices and bunker availability [9], strikes, management, ship crew and port staff competence [10]. External risks have a significant impact on schedules: pandemics [11], military operations, extreme weather conditions, piracy, and terrorism [12].

The most relevant issues of risk analysis and assessment in container shipping are identified in a review [13], where the operational risks, described in the literature were examined according to the following criteria: risk bearer/taker, analysis scale, risk coverage, risk approach, concepts and parameters, and applied methodologies.

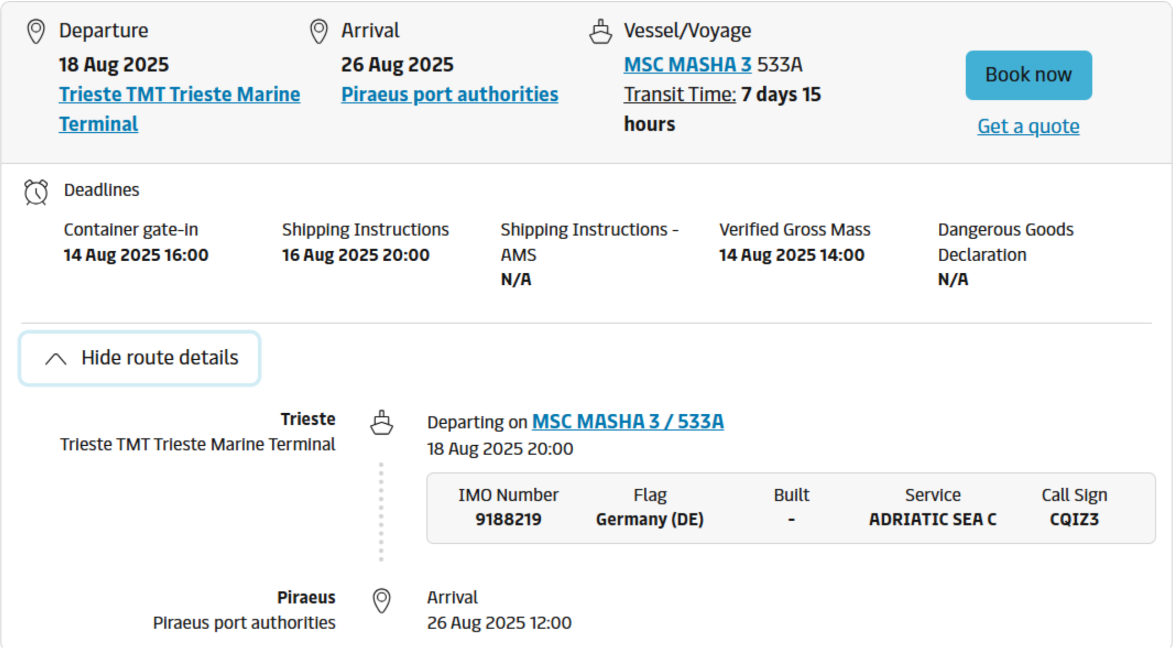
The most recent challenges in risk assessment in liner shipping include: development of a risk-based resilience framework to quantify the effectiveness of recovery strategies designed to address disruptions in liner shipping networks [14]. The article by Elmi et al. [4] concerns the choice of a strategy for rescheduling vessels, which can reduce deviations from the planned schedule and reduce delays in cargo delivery. The focus of the research [15] is on factors causing schedule disruptions. As a result of the study, the authors identified several new factors causing disruptions that had not been sufficiently studied previously, including confirmation that port congestion is the main cause of delays in the work of liner ships. The authors in [16] redefine reliability as a multidimensional performance indicator that combines punctuality, predictability and network robustness. The paper shows that unreliable schedules lead to contractual risks spreading among ports and logistics companies, increasing the likelihood of delay claims and penalty clauses being invoked. It is frequently cited in studies linking operational performance with commercial liability.

Unlike the fault management models described above, which focus either on restoring schedules or optimizing speed, the proposed FCA-based structure focuses on aggregating structural risks at the port level. This assessment provides a transparent aggregation mechanism suitable for supporting management decision-making processes.

## 3. EXPRESS AND REGULAR LINER SCHEDULES

Since any liner schedule consists of information on two characteristics: geographical and temporal, all the risks can be attributed to those that are described as 1). geographical (strategic level), linked with the location where the schedule failure occurred (trade region, ports of call: departure, destination, transit ports, transshipments, etc.); 2). time-related risks (operational level), provide an idea of the deviation from the planned schedule, their origin may be operational management problems, as well as information-related issues and human factors.

Shipping companies independently determine the class of the line and establish their own class (express or regular). The Fig. 1 shows the schedule of the container express line with clearly defined dates/times, and the fig. 2 shows an example of a regular one-way regular car-service line (served by only car-carrier vessels).



| Departure | Arrival | Vessel/Voyage |
|---|---|---|
| 18 Aug 2025<br>Trieste TMT Trieste Marine Terminal | 26 Aug 2025<br>Piraeus port authorities | MSC MASHA 3 533A<br>Transit Time: 7 days 15 hours |

Deadlines

| Container gate-in | Shipping Instructions | Shipping Instructions - AMS | Verified Gross Mass | Dangerous Goods Declaration |
|---|---|---|---|---|
| 14 Aug 2025 16:00 | 16 Aug 2025 20:00 | N/A | 14 Aug 2025 14:00 | N/A |

Trieste
Trieste TMT Trieste Marine Terminal

Departing on MSC MASHA 3 / 533A
18 Aug 2025 20:00

| IMO Number | Flag | Built | Service | Call Sign |
|---|---|---|---|---|
| 9188219 | Germany (DE) | - | ADRIATIC SEA C | CQIZ3 |

Piraeus
Piraeus port authorities

Arrival
26 Aug 2025 12:00

Fig. 1. Express schedule for Trieste-Piraeus section of the ‘SLL Adriatic Sea D’ service (Source: Maersk)

H1 Asia to West Coast America Mexico Service

As of April 2025

(days)

| POL | Position | POD | | | |
|---|---|---|---|---|---|
| | | Lazaro Cardenas | Mazatlan | San Diego | Long Beach |
| Sailing Frequency / Month | | 1/MTH | 1/MTH | 1/MTH | 1/MTH |
| Shanghai/ Japanese Ports | Mid of Month | 20-25 | 22-27 | 27-32 | 27-32 |

| POL | Position | POD | | | | |
|---|---|---|---|---|---|---|
| | | Honolulu | Lazaro Cardenas | Mazatlan | San Diego | Long Beach |
| Sailing Frequency / Month | | 1/MTH | 1/MTH | 1/MTH | 1/MTH | 1/MTH |
| Japanese Ports | End of Month | 10-15 | 20-25 | 22-27 | 27-32 | 27-32 |

Fig. 2. Schedules for car regular service Shanghai-Long Beach and Masan - Long Beach (Source: “K” Line)

As shown above, regular shipping lines may not specify a fixed vessel, do not provide clear dates and times of departure/arrival from ports of departure/destination, and have long intervals between departures.

Regular line schedules often contain the notes “call subject to inducement”; “Indicate an inducement port call that is reliant upon sufficient cargo volume being booked”; “Dates in italics indicate that the port call is not yet confirmed”.

The two opposing positions regarding the content of information published in the schedules by the shipowner are the result of differences in the nature of the cargo base (containerized cargo and cars) and the level of competition in the regions.

Obviously, the requirements for strictness in drawing up schedules, control over deviations from the declared data, and the level of quality of measures to eliminate them will vary.

Although LS is often equated with container transportation in scientific papers, the presented schedules (Fig. 1-2) show how diverse liner markets actually are, the difference in completeness and accuracy of the data in their schedules, and, as a result, the expectations of cargo owners from liner services. Thus, when assessing complex risk factors using any of the expert assessment methods, the competence and experience of experts must be ranked in the context of a specific LS-sector.

## 4. RISK ASSESSMENT APPROACH

It should be noted that these factors are not equally important. Therefore, the significance of these factors depends on the characteristics of the regions through which the ship's route passes and the ports of call. Even the season of the year affects the increase or decrease in the significance of the impact.

Risk assessment is an almost mandatory procedure for any process within any type of activity. For example, for shipping, risk assessment in the context of safety is mandatory, which is proposed to be carried out in accordance with the Formal Concept Analysis (FCA-based) approach, but each company determines the list of risk factors and their significance for assessing the safety of ship operations.

The mentioned FCA methodology corresponds to accepted approaches to risk assessment in any field. Thus, the probability of risk is assessed as an integral value, which consists of the probabilities of individual groups of risk factors and, accordingly, the probabilities of individual risk factors, taking into account their significance. The significance of factors is assessed either by weighting coefficients or by probabilities. The following scheme for assessing the risk of non-compliance with the line schedule is proposed (Fig. 3).

It should be noted that this study only considers the probability of certain events occurring that lead to schedule disruptions. Thus, the main consequence of the occurrence of these events is the exceeding of the time intervals specified in the line schedule. Moreover, this excess can be either significant enough to affect the entire schedule along the entire line, or insignificant, which can be eliminated during the further voyage of the vessel, for example, by increasing the speed between ports. In other words, a minor delay of the vessel in port A will not affect the vessel's arrival at port B on time in such a situation. However, a certain amount of delay in port A cannot be eliminated later, which will lead to the vessel's late arrival at port B. Thus, the consequences of risk factors for schedule disruption may have varying significance for the entire route.

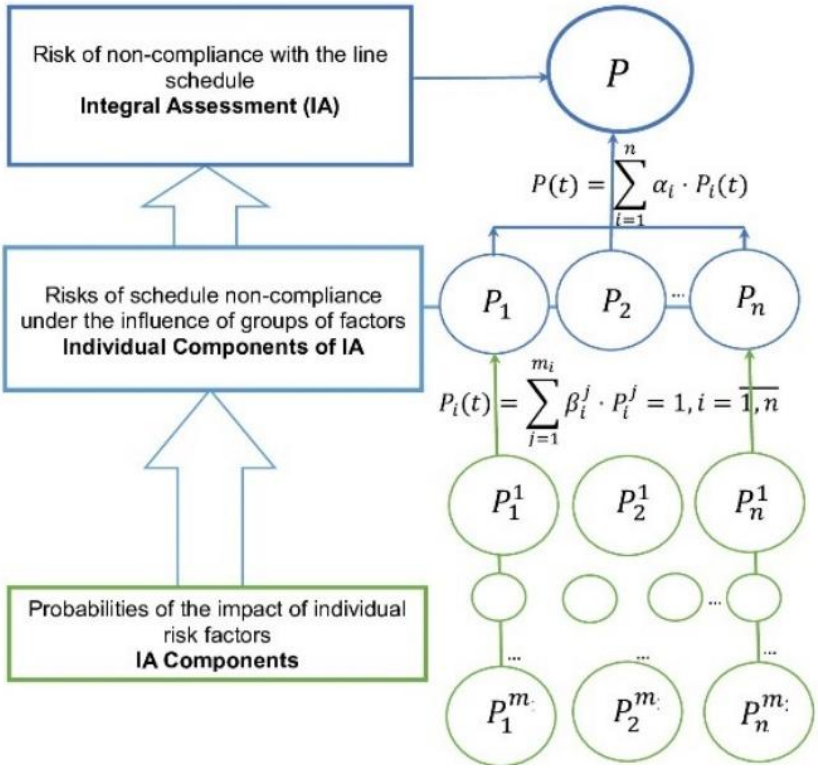


Fig. 3. Formation of risk assessment

Investigation of the consequences of events leading to schedule disruptions is a separate task that involves examining various schedule disruptions in terms of time for each port and for the voyage as a whole. In this study, the main focus is on assessing reliability in terms of the schedule for each port on the line and for the line as a whole, which is a tool for the operator to determine where exactly the line may have a "weak spot" in this context in order to plan and implement appropriate countermeasures or take into account possible delays when planning the line schedule. Thus, it is the probability of the event system that is the focus of this study.

Without loss of generality, we assume that each group of risk factors for schedule non-compliance is characterized by the following set:

$$\{A_i^1, A_i^2, \ldots, A_i^{m_i}\}, i = \overline{1,n}, \tag{1}$$

$A_i^{m_i}$ – are the risk factors of the group $i$, and $m_i$ – the number of factors in the group. It should be noted that in this study, the three global groups of risk factors discussed above are considered, but it is possible to divide the factors into other groups, for example, separating the factors associated with each port, which provides an opportunity for a more detailed further analysis of each risk component.

Thus, each risk factor is associated with an assessment of the probability of the factor's impact at time *t*:

$$\{P_i^1(t), P_i^2(t), \ldots, P_i^{m_i}(t)\}, i = \overline{1,3}, t = \overline{1,T} \tag{2}$$

It should be noted that risk factors are dynamic in nature, taking into account changes in their impact over time. Risk assessment takes place at specific points in time, which is why in this case time is considered as a discrete value, $T$ – the period under consideration.

Risk assessment under the influence of factors of a certain group:

$$P_i(t) = \sum_{j=1}^{m_i} \beta_i^j \cdot P_i^j(t), i = \overline{1, n}, t = \overline{1, T}, \tag{3}$$

$\beta_i^j, i = \overline{1, n}, j = \overline{1, m_i}$ – are the weighting factors that reflect the distribution of the total influence of a group of factors between individual influence factors. As is customary, the following condition is applied to these coefficients:

$$\sum_{j=1}^{m_i} \beta_i^j = 1, i = \overline{1, n} \tag{4}$$

Although these coefficients are not constant values, given that the importance of each risk factor changes over time, this time is usually longer than the term under consideration. Therefore, we assume that these weighting coefficients are reviewed and adjusted periodically, but not at every moment of time $t = \overline{1, T}$, which is why $\beta_i^j, i = \overline{1, n}, j = \overline{1, m_i}$ in (3) they do not depend on time. As a rule, weighting coefficients in risk assessments are established by experts or using appropriate methods that also rely on expert opinions (for example, the method of pairwise comparisons, etc.).

Another remark regarding weighting coefficients – they reflect the impact on non-fulfillment of the schedule. For example, if we consider two factors - delays in the transition between ports and organizational errors in positioning the ship at the berth, then the second factor has, in our opinion, greater weight, because the ship has the opportunity to "catch up" the time required to fulfill the schedule at another transition at a higher speed.

Next, an assessment of the risk of schedule non-compliance (the probability of line schedule non-compliance) is formed under the influence of all groups of factors based on the set $P_i(t), i = \overline{1, n}$ :

$$P(t) = \sum_{i=1}^{n} \alpha_i \cdot P_i(t), t = \overline{1, T}, \tag{5}$$

$\alpha_i, i = \overline{1, n}$ - are the weight coefficients of risk factor groups. As for all weight coefficients, the following condition must be met:

$$\sum_{i=1}^{n} \alpha_i = 1. \tag{6}$$

Similar to the above considerations, these weighting coefficients are not constant, i.e., they need to be periodically reviewed and adjusted in line with changes in the situation, but they are not considered to be time-dependent. In addition, these coefficients are also determined by experts.

Thus, the integral risk of schedule failure can be defined as:

$$P(t) = \sum_{i=1}^{n} \alpha_i \cdot \left( \sum_{j=1}^{m_i} \beta_i^j \cdot P_i^j(t) \right), t = \overline{1, T}. \tag{7}$$

Therefore, (5) and (7) determine the probability of the risk of schedule failure under the influence of multiple factors. Taking into account the essence of the risk assessment components, the range of values of the integrated assessment of the risk of schedule failure and its components is:

$$\begin{gathered} 0 \leq P(t) \leq 1, \\ 0 \leq P_i(t) \leq 1, \\ 0 \leq P_i^j \leq 1, i = \overline{1,n}, j = \overline{1,m_i}. \end{gathered} \tag{8}$$

A separate issue is the determination of probabilities $P_i^j, i = \overline{1,n}, j = \overline{1,m_i}$, which, in fact, form the final risk assessment. As a rule, if the line has existed for a certain period of time, there are statistics on delays and the corresponding reasons for these delays, which makes it possible to establish probabilities statistically. If these statistics are missing or insufficient, it is necessary to rely on expert opinions.

It should be noted that the purpose of risk assessment is, first and foremost, to monitor changes in the impact of risk factors and to identify trends that are “critical” for schedule compliance for individual risk factors in specific ports and specific areas of vessel traffic. This makes it possible to implement appropriate management actions, such as organizational measures to minimize the impact of certain risk factors, or changes to the schedule of ships on the line if it is impossible to influence the risk factors.

Next, as is customary in any field, the use of risk assessments should be based on determining the degree of risk according to a specific scale. Depending on the field of application, different authors introduce different ranges of risk assessment values for its classification. The risk scale is determined by many factors, including the attitude of the company and managers who make decisions regarding risk management towards risk; the specifics of the activity and the consequences of the impact of risk factors. For some areas, a risk of 2 % is already high (for example, when it comes to the operation of technical equipment), while for commercial activities, a risk of 5 % in an economic context is considered a “normal” level. Therefore, in this case, the following scale can be used:

- $0 \leq P(t) < 0{,}02$: risk is almost non-existent;
- $0{,}02 \leq P(t) < 0{,}05$: risk is moderate;
- $0{,}05 \leq P(t) < 0{,}1$: risk is noticeable;
- $P(t) \geq 0{,}1$: risk is high.

It should be noted once again that the implementation of a specific risk classification scale depends on the attitude of the carrier's management towards the risk of schedule violations. Therefore, the above option is one of several possible options. For example, for a company operating in a complex, competitive environment for a particular line, a “significant” risk may be defined at a level of 0.03. Conversely, for some carriers, a risk of 0.1 is not high. Thus, the company's attitude to risk, the characteristics of the geographical segment of the line, and the characteristics of the competitive environment justify both the list of influencing factors and their weight, as well as the determination of the degree of risk.

To demonstrate how the proposed method works, let us consider the following example. We accept three groups of risk factors, which are grouped by transshipment ports and corresponding route segments (Fig. 4).

For each group, four risk factors are accepted: failure to comply with ship handling standards at the port; delays due to bunkering; delays in ship transit due to weather conditions; errors in ship positioning. These factors have the same weighting coefficients for different ports, but for other situations, these coefficients may differ.

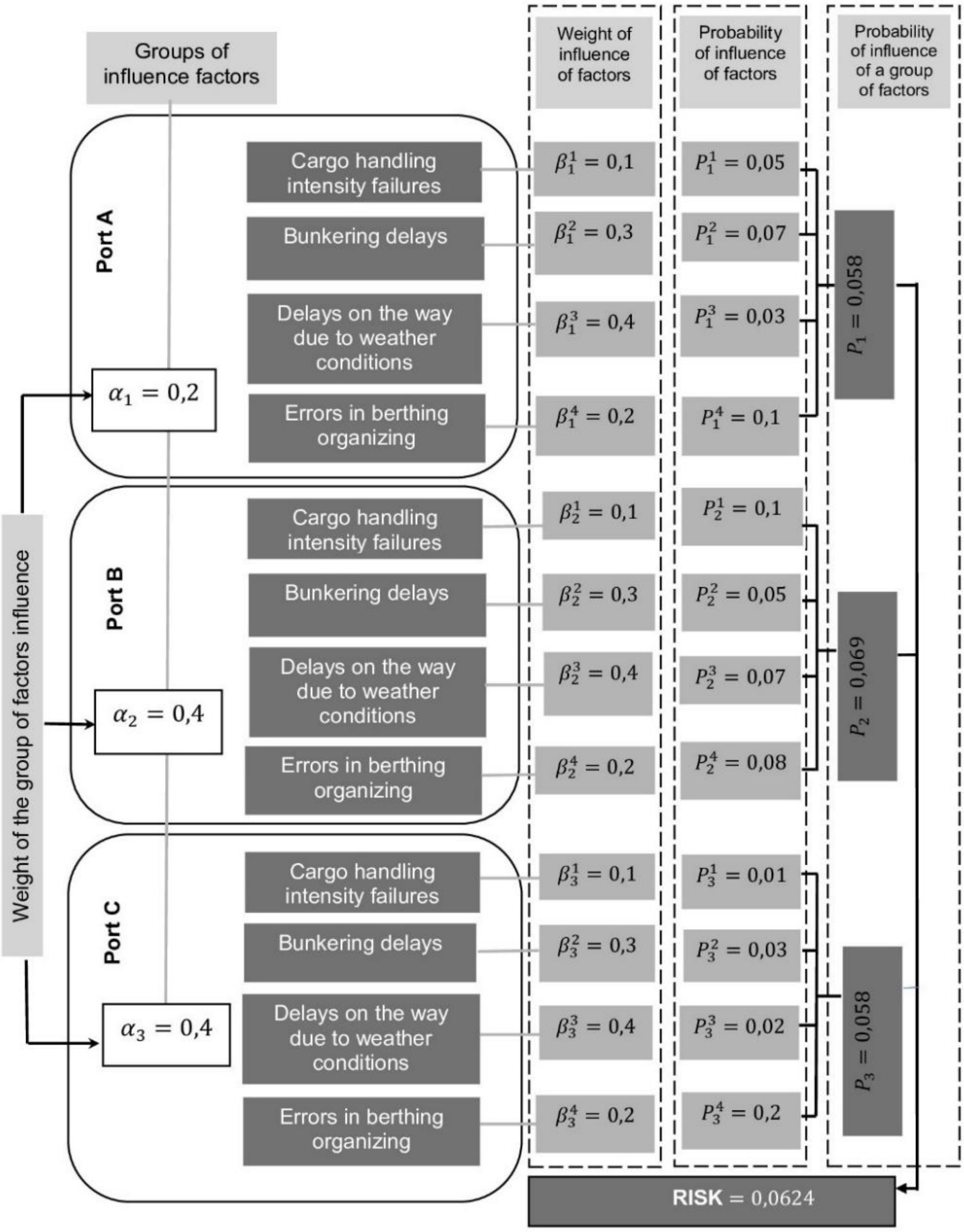


Fig. 4. Numerical example of assessing the risk of schedule failure

If, for example, in port *A*, errors in docking a ship usually cause more significant delays than in port *B*, then for this situation, the corresponding weighting coefficient for port *A* should be greater than for port *B*. Thus, these weighting coefficients $\beta_i^j$ allow the risk to be assessed in accordance with the actual situation. The initial data for assessing the probability for each risk factor are also shown in Fig. 4.

We assume that the following weighting coefficients $\alpha_1 = 0{,}2; \alpha_2 = 0{,}4; \alpha_3 = 0{,}4$ correspond to the groups of factors, and this distribution is accepted, taking into account the greater importance of ports *B* and *C* in the operation of the line.

Thus, the coefficients $\alpha_i, i = \overline{1,n}$ allow us to differentiate between groups of factors depending on their impact on the integral risk. Taking into account the accepted initial data for the time period under consideration, we have the following values for the group and integral risk assessment of schedule disruption:

$$P_1 = 0{,}058, P_2 = 0{,}069, P_3 = 0{,}058, P = 0{,}0624.$$

Fig. 5 shows a comparison of the probabilities of the impact of risk factors for schedule non-compliance for each group (in this case, ports). It can be seen that Port *A* is characterized by a lower level of potential impact of risk factors compared to other ports. Port *C* has the highest probability of error in organizing the berthing of a vessel, but given that the weight of this factor is not very high – $\beta_3^4 = 0{,}2$, the overall risk associated with this port, $P_3$, is equal to the risk $P_1$associated with port *A* (Fig. 7, option 1). The total risk is $P = 0{,}0624$.

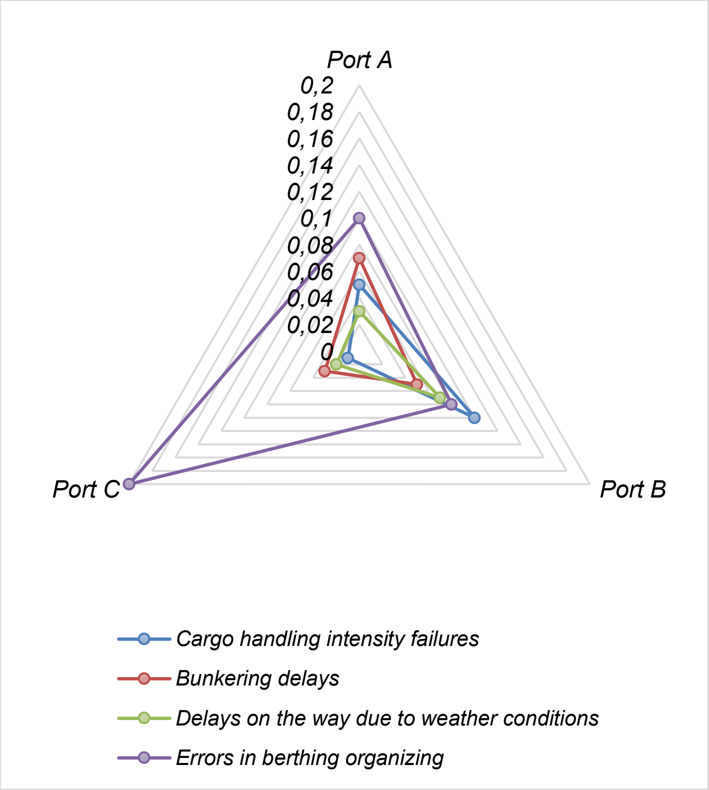


Fig. 5. Comparison of risk factor assessments for the line's ports of call

However, if we accept a different distribution of risk factor weights, namely:

$$\beta^1 = 0{,}1, \beta^2 = 0{,}3, \beta^3 = 0{,}2, \beta^4 = 0{,}4,$$

i.e., the fourth risk factor in each group now has the maximum weight, we obtain the probabilities by risk group (port) as in Fig. 6, option 2.

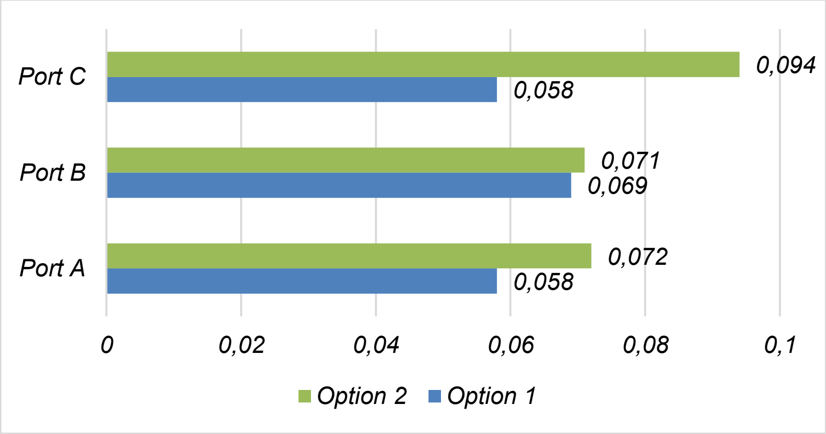


Fig. 6. Comparison of risk assessments for groups of factors (by ports of call)

The risk (in the context of interpreting its assessment) has become significantly higher, with the overall risk assessment now equal to $P = 0{,}0806$.

Therefore, the results of the assessment of the risk of non-compliance with the schedule, in terms of their correspondence to the actual operating conditions of ships, undoubtedly depend on how correctly not only the risk factors are assessed, but also their significance.

When comparing option 1 and option 2, it should be noted that for the first situation, the overall risk is 0.06, which is slightly higher than the “normal” or ‘moderate’ 0.05. However, for the second option, the risk is already higher and equals more than 0.08, which is already a “significant” risk.

Therefore, the weighting of risk factors and groups of factors should be based on an analysis of statistical data supplemented by expert assessments. This task was not addressed in this study, so the result is a proposed method for assessing the risk of line schedule non-compliance and a concept for forming risk factor groups, as demonstrated by a specific example.

## 4. CONCLUSION

Thus, a method for assessing the risk of non-compliance with the line schedule is proposed, which is based on a well-known approach, the essence of which is to take into account a set of risk factors and their probabilities, as well as the corresponding weighting coefficients, which allow differentiating the significance of each factor into a general integral risk assessment. Thus, the known method is extended to solve the problem of assessing the risk of schedule non-compliance, which enriches the theory of ship operation management. The main risk factors for schedule non-compliance have been identified, and relevant experimental studies on the use of the proposed method have been conducted. The proposed model enables key decision-makers to evaluate alternative liner routing structures, reconsider port rotation to optimize operational strategies based on quantified risk indicators. The practical application of this method will allow monitoring of the schedule of the line for the timely identification of problems with schedule compliance and appropriate response, which will increase the efficiency of ship operation management processes on the lines and the functioning of the line service in general. Possibilities for further expansion of the model include integration with FMEA and FTA methods for more in-depth cause-and-effect analysis, adding indicators of the severity of consequences, application to the design of linear transport schedules across the entire network, and interfacing with simulation and decision support systems.

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