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Ričardas Maksimavičius

RESEARCH OF RO-RO FREIGHT ON THE BALTIC

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Scientific Supervisor:

Prof Dr Habil Vytautas Paulauskas (Klaipeda University, Technological Sciences, Transport Engineering – 03 T)

The dissertation is defended at the Council Of Scientific Field of Transport Engineering at Vilnius Gediminas Technical University:

Chairman:

Prof Dr Habil Adolfas Baublys (Vilnius Gediminas Technical University, Technological Sciences, Transport Engineering – 03T)

Members:

Prof Dr Habil Alvydas Pikūnas (Vilnius Gediminas Technical University, Technological Sciences, Transport Engineering – 03T)

Prof Dr Habil Jonas Sapragnas (Kaunas University of Technology, Technological Sciences, Transport Engineering – 03T)

Prof Dr Habil Sergejus Lebedevas (Klaipeda University, Technological Sciences, Transport Engineering – 03T)

Prof Dr Habil Leonas Povilas Lingaitis (Vilnius Gediminas Technical University, Technological Sciences, Transport Engineering – 03T)

Opponents:

Prof Dr Habil Algirdas Jurkauskas (Kaunas University of Technology, Technological Sciences, Transport Engineering – 03T)

Assoc Prof Dr Nijolė Batarlienė (Vilnius Gediminas Technical University, Technological Sciences, Transport Engineering – 03T)

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Address: Saulėtekio al. 11, LT-10223 Vilnius-40, Lithuania

Tel. +370 5 274 49 52, fax +370 5 270 01 12

e-mail doktor@adm.vtu.lt

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Ričardas Maksimavičius

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prof. habil. dr. Vytautas Paulauskas (Klaipėdos universitetas, technologijos mokslai, transporto inžinerija – 03T)

Disertacija ginama Vilniaus Gedimino technikos universiteto Transporto inžinerijos mokslo krypties taryboje:

Pirmininkas:
prof. habil. dr. Adolfas Baublys (Vilniaus Gedimino technikos universitetas, technologijos mokslai, transporto inžinerija – 03T)

Nariai:
prof. habil. dr. Alvydas Pikūnas (Vilniaus Gedimino technikos universitetas, technologijos mokslai, transporto inžinerija – 03T)
prof. habil. dr. Jonas Sapragnas (Kauno technologijos universitetas, technologijos mokslai, transporto inžinerija – 03T)
prof. habil. dr. Sergejus Lebedevas (Klaipėdos universitetas, technologijos mokslai, transporto inžinerija – 03T)
prof. habil. dr. Leonas Povilas Lingaitis (Vilniaus Gedimino technikos universitetas, technologijos mokslai, transporto inžinerija – 03T)

Oponentai:
prof. habil. dr. Algirdas Jurkauskas (Kauno technologijos universitetas, technologijos mokslai, transporto inžinerija – 03T)
doc. dr. Nijolė Batarlienė (Vilniaus Gedimino technikos universitetas, technologijos mokslai, transporto inžinerija – 03T)

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Adresas: Saulėtekio al. 11, LT-10223 Vilnius-40, Lietuva
Tel. +370 5 274 49 52, fax +370 5 270 01 12
el.p. doktor@adm.vtu.lt

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Introduction

Currently Port of Klaipėda has been interlinked by ro-ro transit lines with Germany, Sweden and Denmark. It has been sought not only for improvement but also for development and expansion of the ro-ro market in order to answer continuously growing needs of clients.

Lithuanian ro-ro liner shippers and operators although confronted by severe competition in ro-ro shipping market, strive to retain their position, conquer and manage new ro-ro markets. Yet it is to be mentioned that close cooperation with other transport industries and ro-ro terminals is not always attainable what consequently enhance the impact of factors affecting ro-ro transport and lessen attractiveness of such transportation, reduce cargo flow in general.

Relevance of the problem. Considerable part of ro-ro lines are forced to close down soon after they are opened as having no prospects for they fail to attract sufficient freight and cargo flow due to multiple reasons like inadequate assessment and underestimation of advantages, shortcomings and risks (threats) and overestimated possibilities, insufficient research into cargo flow, inconsideration or failed acknowledgement of factors affecting ro-ro transportation. Therefore the **relevance** of the issue involved in this dissertation reveals not only for developing of new ro-ro shipping lines, but also for restructuring of existing lines and restoring of former ro-ro lines, it applies also in view of intended increase in competitiveness of ro-ro freightage against other cargo transports.

The purpose of the Dissertation is theoretical investigation of the principles of ro-ro transport and assessment of factors affecting ro-ro market, and possibilities for appropriate development and optimization of ro-ro, and based on these establishing the factor assessment model with further enabled experimental application thereof.

Key tasks are:

- Establish objective and subjective factors and their respective impact on ro-ro liner shipping;
- Develop a complex assessment model for ro-ro shipping;

- Apply the classical forecast methods while evaluating the specifics of ro-ro freight and potential crises in ro-ro flows;
- Practical-experimental verification (approbation) of the research methodologies and models set up herein.

Novelty of the dissertation:

Revised methodology of ro-ro flow forecasts clearly defined factors to affect ro-ro freight and established model for complex assessment of factors likely to affect ro-ro shipments on the Baltic are used for further substantiation of ro-ro shipping prospects. Theoretical grounding regarding minimization of ro-ro ferry lading time has been carried out to find out appropriate required quantity of entrance gates, control units and parking spaces in the terminals.

These principal provisions have been maintained in the dissertation:

- Application of the methodologies for research of the specifics of ro-ro shipping on the Baltic;
- Key factors to affect ro-ro freightage on the Baltic;
- The complex assessment model for objective and subjective factors to impact ro-ro freight on the Baltic and overall criterion term to estimate the expediency of transportation;
- Updated cargo-flow forecast methodology to base the ro-ro lines' prospects by evaluating of critical cargo flow;
- Minimization of ro-ro ferry lading time at port based on the recently adopted ISPS Code.

Practical weight of the dissertation: Diverse models for investigation of factors affecting ro-ro transport presented in the work might be applicable in development of new ro-ro lines, refurbishment of existing lines and re-structuring of the closed facilities by due consideration of both subjective and objective factors that are likely to influence ro-ro transportation. Minimization of ship's loading time at port.

Approbation of the dissertation. Principal statements of the dissertation have been approved at 5 scientific and research conferences and published in 9 research periodicals.

Coverage and structure. The dissertation consists of the following parts: Introduction, 5 Chapters, Basic Conclusions, Literary References and 6 Annexes. The work is laid out on 128 pages. The paper includes 15 Figure and Charts and 12 Tables. Reference list covers 110 publications.

1. Literary Survey

Relatively few research works related to ro-ro shipping have been delivered over last decade. Significant research and studies on transport economics and logistics have made an effect on ro-ro shipping developments. Over recent years the CTU (Cargo Transport Unit) factor has been seriously considered in many respect for “pushing” it onto the sea, railways, inland waterways transport alongside with a noticeable aspiration and active input of researchers for implementation of this concept.

Studies from foreign and Lithuanian authors in the area of ro-ro and short-distance shipping (SDS) have classified the works into the following according to the area of investigation:

- Possibilities of freight transfer into ro-ro and SDS lines;
- Improvement of ships’ technical parameters and technical development of the fleet;
- Overall development and adjustment of ports for ro-ro services;
- Improved organization of structures to handle ro-ro services;
- Multimodal aspect and advantages of multimodal transportation;
- Implementation of IT techniques and search for innovative solutions for better port and line servicing;
- Logistics and its importance;
- Improvement of law and legislation.

The research works have considered multiple factors yet some of them not sufficiently or not applicable to ro-ro field. Thus relative solutions related to ro-ro shipping are considerably hard to be made.

As neither Lithuanian nor foreign studies have provided in-depth analysis on separate elements like entering and check-ins at ro-ro terminals in view of ISPS Code implementation, also inadequate research of compatibility of new ports toward ro-ro shipping, the methodologies introduced failed to cover all these items.

Therefore for proper investigation of ro-ro shipments on the Baltic models of factors likely to affect ro-ro transportation have been introduced and followed by a complex model that has been subject to experimental verification; theoretical substantiation for minimization of lading time at port that would ensure appropriate quantity of entrance gates, control units and parking spaces at the terminal.

2. Ro-ro Transportation on the Baltic

Currently around 51 ro-ro lines operate on the Baltic and the number is subject to continuous change due to the impact of various factors. Having investigated the existing ro-ro lines and operators on the Baltic, main factors most likely to impact ro-ro business have been established that are to be seriously considered in order to considerably improve ro-ro market condition.

In ro-ro investigations, it is essential to apply complex evaluation both to the ro-ro liner operators and ports, since any presence of negative factor will badly impact the current ro-ro transport.

Negative factors to affect ro-ro transportation have been established: inadequate access to the ro-ro terminals; port channel infrastructure insufficient for extensive shipping; inadequate relationship of ports, ro-ro terminals and ro-ro operators in respect of ro-ro transportation; incorrect attitude toward cargo flow fluctuation possibilities; restricted flexibility of ro-ro freight charges due to large running costs; impact of natural calamities on ro-ro linear shipping; no set tradition and business mode at newly opened ro-ro facilities; improper organization of ro-ro terminals operation; shortage of technical possibilities in ro-ro linear shipping; inadequate IT infrastructure within ro-ro terminals; lay-up and outage due to natural adversities and improper organization of terminal operation, in particular at brand-new ro-ro facilities; significant impact from accidents and incidents on ro-ro

freight flow; extensive investments required for terminal facilities; partial or total underestimation of factors; other ro-ro related shortcomings likely to affect transportation; competition between railways and motorways; unstable political and economical situation is likely to affect almost all freightage areas in general, yet on ro-ro shipping it may have an undesired influence related to increased safety requirement imposed by ISPS Code.

Therefore for due assessment of above ro-ro related flaws and possible elimination thereof it is necessary to implement effective cargo flow forecast methodologies, clearly define factors affecting ro-ro transport, modelling and complex evaluation of ro-ro factors in order to enable their minimization and elimination. Due to stringent cargo control at ports it is necessary to set a theoretical substantiation of ro-ro ferry lading time minimization at port that would ensure due quantity of entrance gates, control units and parking spaces at the terminal.

3. Methods of Ro-ro Shipping Investigation on the Baltic

While performing research on ro-ro transportation or shipping lines it is essential to take into account possible cargo flows in the future, i.e. necessary to provide due forecast for potential cargo flows.

Ro-ro flows in many cases may be rated as accidental values. For due estimation of current situation and forecast any potential situations statistical methods are applied.

The cargo flow statistical prognosis is based on the prevailing current and past conditions and analysis of their stochastic characteristics.

It has been found that the investigated ro-ro flow forecast methods may serve as simple and convenient provided for that ro-ro flow condition have been unchanged for an extensive term of time. However, subject to changed condition for o-ro transportation, linear methods of forecast may appear as considerably inaccurate and turn out to be out of use.

Possible ro-ro flow situations and inaccuracies in the linear forecast method we may set out into the following groups (Fig. 1):

- Long-term stable and even ro-ro flow;
- Ro-ro flow under critical change condition;
- Ro-ro flow under a single huge change (crisis).

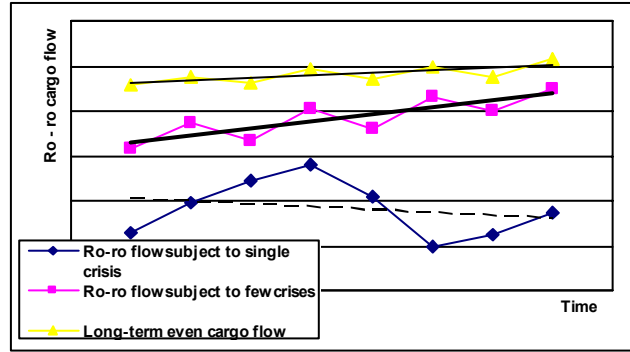


Fig 1. Possible ro-ro situations and inaccuracies subject to linear forecast methods

Linear forecast method is applicable under the stable flow rate or when only few changes are present (Fig 1.), yet this method is rather incorrect under a single crisis situation what may result in significant inaccuracies.

In order to avoid significant forecast rating mistakes we make use of a multi-criteria evaluation that may be formulated as follows:

$$M = \frac{1}{\eta_k} \sum f_i N_i, \quad (1)$$

here: f_i – weight quotients of factors affecting ro-ro flow forecasting;
 N_i – individual factors; η_k – correlation quotient.

Then the forecast result will be found as follows:

$$Q_i = (Q_0 + BT)M, \quad (2)$$

here: Q_0 – ro-ro freight flow at the last available point; B – coefficient set by statistical information; T – forecasted period.

In order to establish a forecast error a mean square error method is applicable. Weights of the factors, values and correlations are found out through regression equation based on the available information.

Normally flow rate intensity is variable and depends on multiple factors. For relative supply of ro-ro flows to secure the increase, not decrease of flow rate, it is sometimes necessary to increase the ro-ro flow intensity. This is relevant of seasonal freightage. Thus it is expedient to apply stochastic methods.

If we assume P as a favourable probability for ro-ro freight, and Q as unfavourable possibility, then we have favourable possibility valued as:

$$P = 1 - Q. \quad (3)$$

Having the value of possibility of periodical/recurrent ro-ro transportation as P_{ro-ro} , we may figure out freight intensity E_{ro-ro} as follows:

$$E_{ro-ro} = \frac{1}{P_{ro-ro}}. \quad (4)$$

Ro-ro freight intensity must be considered as, say, inadequate number of ships per ro-ro line may cause multiple inconveniences in respect that part of the cargo might be left behind undelivered what might be the reason for the decrease in cargo flow.

For establishing ro-ro freight intensity it is necessary to define the intensity of ro-ro transportation by ships. For ro-ro freight flow intensity we may use the methodology explained above and rate the ro-ro transportation intensity.

Thus having evaluated the intensity of ro-ro freight flows and ro-ro transportation intensity, we may establish appropriate ro-ro transportation rates through comparison of them, and accordingly ensure better freight condition.

Through analysis of costs and profits it is possible to find out when after having exceeded the zero-profit margin and at gainful state of business it is expedient to moderate the income gain as in such a situation the company has apparent advantages in front of other competitors and is capable of reducing, say, freight charges or dedicating more attention to answer the client's needs, by retaining the status of a well-standing company

4. Modelling of Factors Affecting Ro-ro Transportation

Based on the methodology for ro-ro investigation on the Baltic, factors that are likely to impact ro-ro shipping are modelled. The model of such factors has to imply the following:

- objective factors:
 - freight charges;
 - freight delivery time.
- subjective factors:
 - safety of the cargo;
 - possibility to change the transport route;
 - freight insurance;
 - banking operation system;
 - other factors.

For evaluation each of the above factors a general model of factors affecting ro-ro transportation is set (Fig 2.).

Each of the factors is marked with separate relative quantities: P_i – freight charge; T_i – freight delivery time; S_i – cargo safety; L_i – possibilities to change transportation route; D_i – freight insurance factor; B_i – banking system evaluation; N_i – other factors evaluation.

The impact of all factors may be delivered as below:

$$M = P_i + T_i + S_i + L_i + D_i + B_i + N_i. \quad (5)$$

In order to estimate general impact on ro-ro transportation it is

necessary to produce thorough evaluation of each components of factor model, as the final result will depend on this.

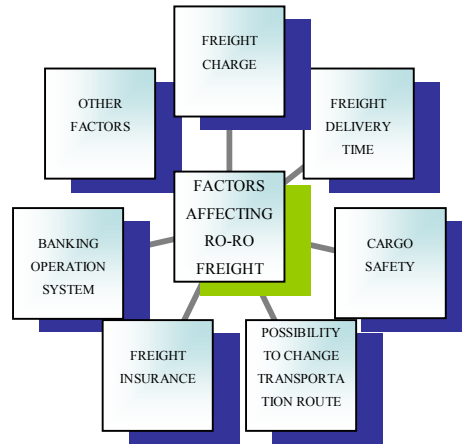


Fig. 2. General model of factors affecting ro-ro transportation

Given the evaluation of freight charge factor we should not single out marine transportation charge, as in ro-ro operation there are necessary other supplementary services that will finally comprise the whole freight charge.

Freight charge may be expressed this way:

$$P_i = P_{vi} + P_{Ti} + P_{Pi} + P_{Ri} + P_{Bi} + P_{Di} + P_{\Delta i} + P_{VT_i} + P_{IT_i}, \quad (6)$$

here: P_{vi} – freight charge by ro-ro ferries; P_{Ti} – freight processing charge at terminals; P_{Pi} – extra charges (for extra services); P_{Ri} – port dues and ro-ro terminal charges; P_{Bi} – bank services dues; P_{Di} – freight insurance bonus; P_{Δ} – extra expenses; P_{VT_i} – freight charge from the consigner to ro-ro terminal; P_{IT_i} – freight charge from ro-ro terminal to the end-recipient.

Given the known components of freight charge we modify the

evaluation of freight charge factor:

$$P_i = n_1 P_{vi} + n_2 P_{Ti} + n_3 P_{Pi} + n_4 P_{Ri} + n_5 P_{Bi} + n_6 P_{Di} + n_7 P_{\Delta i} + n_8 P_{VT_i} + n_9 P_{IT_i}, \quad (7)$$

here: n_i – freight charge factor weight coefficients to be set on the basis of expert investigation.

Using this modified evaluation of freight charge we may find out what integral parts of the freight charge factor will imply the largest weight in ro-ro transportation and consequently produce the utmost influence on freight charge. It is thus possible to find out what freight charge factor parts should be influenced in order to achieve greater advantages for ro-ro freight transportation.

Time consumed for freight deliveries is an urgent factor in deliveries of expensive cargoes with short term of validity. We have to seriously consider the timely delivery of freight to the consignee. In this respect they always strive to work out an optimal route that would imply least time consumption.

Modified ro-ro freight delivery time factor may be written down as this:

$$T_{vi} = T_{vai} t_1 + T_{vli} t_2 + T_{vli} t_3 + T_{vij} t_4 + T_{vaj} t_5 + T_{\Delta vi} t_6, \quad (8)$$

here: t_i – freight delivery time component weight to be set through expert investigation; T_{vai} – freight delivery time from the sender to the ro-ro terminal; T_{vli} – freight delivery (by ships) time in-between ports; T_{vli} – freight processing time at ro-ro terminal that depends on multiple factors i.e. freight nature/origin, procedures, lading rate at the port etc.; T_{vij} – freight processing time at the other ro-ro terminal, to be calculated analogous to that of processing time at the primary ro-ro terminal; T_{vaj} – freight delivery time from ro-ro terminal station to the freight consignee, estimated same as T_{vai} ; $T_{\Delta vi}$ – extra time required for all ro-ro transportation, that depend on the procedure, driver rest time,

convoy waiting time etc.

Here it is necessary to estimate both freight delivery time by ships and all the time required for the freight to reach the terminal because what matters to cargo consignor and consignee is freight delivery to its destination.

Cargo safety is of utmost importance not only to the shipper, but also to the consigner and the consignee. Freight shipper risks lay at its direct losses, meanwhile the consignee is at by far bigger risk, even though he has been indemnified against undelivered or damaged goods and will be entitled to the insurance compensation yet he may incur losses due to improper supply of manufacturing chains.

Cargo safety factor may be evaluated based on the relative values and cargo safety factor weights:

$$S_i = s_1 S_{vi} + s_2 S_{ti} + s_3 S_{li} + s_4 S_{tp} + s_5 S_{vg} + s_6 S_{\Delta i}, \quad (9)$$

here: s_i – cargo safety factor weights to be set up in statistical way;

S_{vi} – cargo safety en route to ro-ro terminal.

Cargo safety en route ro-ro terminal to the end recipient value S_{vg} is defined same as freight delivery from consignor to the ro-ro terminal.

Cargo safety at ro-ro terminals in fact is subject at large to possible theft, loss and damage.

S_{ti} – cargo safety at the dispatch terminal.

Cargo safety at the reception terminal S_{tp} is calculated same as that at the dispatch terminal.

Cargo safety during ro-ro deliveries by sea depend on both ship's reliability and technical qualities and the proficiency of the crew.

S_{li} – cargo safety during sea freight.

Over the last decade multiple marine safety codes and laws have been adopted and passed to ensure and increase ships safety both theoretically and practically.

Additional cargo safety factor $S_{\Delta i}$ relies on various casual impacts

such as overloads at ro-ro terminals, check-outs etc. In this respect a CTU safety may not be subject to evaluation, only considering the cargo safety factor that is inside a CTU, as direct contact may be established to that.

Extra freight safety factor is considered only when there is a possibility for a direct contact with the cargo. So by using the set estimation for cargo safety in ro-ro freightage we can see what points in the ro-ro freight transportation are the weakest ones and which points require increased cargo safety in order to maintain stable cargo flow.

Possibility to change sailing route is important when there are appear some unforeseen hindrances. It can be rated in points and compared to analogous ro-ro shipping liner service or road transport regardless of what is the competitor.

Ro-ro linear shippers do not exercise changing of sailing routes in short distance shipping, yet these are not possible due to the formed cargo flows.

Insurance indemnity is an important factor to both freight consignor and consignee as the insurance benefit (compensation) is directly related to the freight charge. Majority of insurers apply lower indemnity rates for ro-ro transportation by sea.

However freight insurance factor evaluation in ro-ro ships alone would not be completely accurate as ro-ro terminals get involved in ro-ro freightage directly, it is thus necessary to consider the influence of operation of ro-ro facility on the freight insurance in ro-ro transportation. In other words, freight insurance factor has to undergo complex assessment.

Thus we can produce freight insurance factor as follows:

$$D_i = d_1 D_{at} + d_2 D_l + d_3 D_{it}, \quad (10)$$

here: d_i – freight insurance factor weights to be based on the expertise investigation; D_{at} – freight insurance factor at the destination terminal; D_l – freight insurance factor onboard ro-ro ferry; D_{it} – freight insurance factor at the departure terminal.

Therefore modified evaluation of freight insurance factor in ro-ro transportation provides a rather exact impact range on ro-ro freight, as the very insurance premium rate will depend upon freight safety and insurance factor ratings, what will influence the freight charges in total based on the insurance premium size.

Bank system operation is mostly evaluated based on the bank stability and solvency ratings since banks are responsible for any possible threat of losing the funds paid for the freight and transportation thereof.

Customers to ro-ro linear services may encounter inconveniences related to booking the tickets/stations and prepaying for freight via bank transfer.

In other factors and their effect we most often come across with the following issues: work experience; availability of qualified specialists and performance; availability of service agents and their experience in the industry; potential weather calamities; position of ro-ro shipping lines on the world market.

Thus a modified assessment of other factors may be stated as follows:

$$N = n_1N_1 + n_2N_2 + n_3N_3 + n_4N_4 + n_5N_5, \quad (11)$$

here: n_i – weight coefficients of other factors to be based on expert research; N_i – other factors.

Complex assessment of ro-ro factors is generally possible through the application of a modified model of factors affecting ro-ro transportation. Then:

$$E = \eta_k (k_1P_i + k_2T_i + k_3S_i + k_4L_i + k_5D_i + k_6B_i + k_7N_i), \quad (12)$$

here: η_k – correlation factor; k_i – weights of factors impact on ro-ro freight.

Factor weights are established through expert evaluation. In ro-ro market factor weights are directly linked to factor's importance. In

some cases the priorities of factor may change, for instance – under the effect of natural calamities.

Therefore factors affecting ro-ro transport may be resulted as follows:

$$\Delta = \frac{E_i}{E_j}, \quad (13)$$

here: E_i – comparative result of the ro-ro freight under research; E_j – comparative result of other transports.

The relative comparison of freightage indicates which transport industry is less affected by such factors and thus remains more favored for transportation.

In this way through complex assessment of ro-ro freight and relative assessment of transportation it is possible to determine what kind of transport are more attractive. Also there is a possibility while duly affecting some or other factors to make the freight more attractive for the customer. Not only rival ro-ro lines can undergo this complex assessment for comparison thereof, yet other parallel transport industries and branches.

Expert evaluation is based on 10 score system. Number of companies involved in ro-ro transportation rates every factor and factor's sub factor using appropriate score depending on importance of the sub factor or factor.

Mathematical statistics and probability theory methods are used to process the results. Range values and range of reliability is calculated witch gives the probability 0,99 it means that such factor or sub factor is necessary.

Verifying the minimum number of companies participating in expert evaluation, when reliability probability $\beta = 0,99$ and precision $\varepsilon = 1$.

It is necessary to calculate variation line:

$$\Delta = \frac{a_s - a_0}{s}, \quad (14)$$

here: a_s – top score; a_0 – minimum score; s – number of scores.

Factor's and sub factor's range of reliability, when $\beta = 0,99$:

$$I_{\beta} = \left(\bar{x} - \frac{\sigma t_{\beta;n}}{\sqrt{n}}; \bar{x} + \frac{\sigma t_{\beta;n}}{\sqrt{n}} \right), \quad (15)$$

here: $\bar{x}$ – average; σ – standard; n – number of companies participating in expert evaluation;

The minimum number of companies which must participate in expert evaluation to achieve sufficient range of reliability:

$$n = \frac{\sigma^2 t_{\beta}^2}{\epsilon_{\beta}^2}. \quad (16)$$

Total evaluation of factor's sub factors $A_{p_i} = \sum A_{p_n}$, factors $A_{v_i} = \sum A_{v_n}$ and total evaluation of all factors $A_{vv} = \sum A_{v_i}$ must be calculated for evaluation of the weight coefficient. Then weight coefficient of sub factor:

$$n_i = \frac{A_{p_i}}{A_{v_i}}, \quad (17)$$

and weight coefficient of the factor in complex evaluation:

$$k_i = \frac{A_{v_i}}{A_{vv}}. \quad (18)$$

If due expert evaluation, the evaluation results sufficiently differs, depending on n additional expert evaluation is necessary, it means results of evaluation must be qualified or additional companies must participate in expert evaluation.

Proper arrangement and compatibility of ship and port operation are essential factors to affect ships' lading time. Statistically it has been proven that major part of freight (ca 80 %) are delivered by CTU (vehicles) to ro-ro terminal only 2–3 hours prior to ship's depart. Thus it is during these peak hours that basic terminal services and units receive maximum load for handling.

Adequate number of ro-ro terminal entrance gates are very important both for the efficient operation of the terminal and ships processing rate. As inadequate (shortage) entrance facilities are likely to cause congestions at the terminal gateway, and the check-in points will be subject to inadequate load which eventually in its own way will affect the ferry lading rate and time.

General CTU processing intensity at the gateways can be rated as follows:

$$\mu = \frac{G}{t_{apt}}, \quad (19)$$

here: G –number of gateways at ro-ro terminal, in pcs.; t_{apt} – a CTU processing time, in min.

As an alternative we may choose a single-track or multi-track gateway entrance system.

The arriving trucks at the ro-ro gateways are spread as per Poisson law at the intensity rated as λ . Accordingly, CTU processing time is distributed according to exponential law. On condition, that for normal standard terminal gateway operation entrance load φ should not exceed one:

$$\varphi = \frac{\lambda}{\mu} < 1, \quad (20)$$

Then minimal number of gateways $G_{\min}$ per set CTU flow has to be:

$$G_{\min} = \lambda \cdot t_{apt}. \quad (21)$$

Otherwise we fail the absolute reliability and subsequently the required CTU quantities cannot be accepted.

Thus average waiting time outside terminal will be:

$$W_e = \frac{\varphi}{(1-\varphi)\mu} . \quad (22)$$

Average time for entry to the terminal per CTU will be:

$$W = W_e + t_{apt} = \frac{\varphi}{(1-\varphi)\mu} + t_{apt} = \frac{\lambda t_{apt}^2}{B(B - \lambda t_{apt})} + t_{apt} . \quad (23)$$

On condition $W \leq T$, where T means relative time, e.g. boarding check-in of CTU and ferry boarding completion time, we have:

$$G^2 - \lambda t_{apt} G - \frac{\lambda t_{apt}^2}{T - t_{apt}} \geq 0 . \quad (24)$$

An estimated required number of ro-ro terminal gateways is defined as the minimal whole number result in this inequity.

Average number of CTU awaiting at the terminal gateways is:

$$L_q = \frac{\varphi}{1-\varphi} . \quad (25)$$

Average queuing line of CTU per terminal gateway pass-point will be:

$$R_q = \frac{L_q}{G} = \frac{\varphi}{(1-\varphi)G} . \quad (26)$$

Therefore terminal entrance pass-points and export grounds access have to be designed based on the average number of CTU

vehicles awaiting at terminal gateway p_q , and average CTU line length to queue per single gateway L_q .

This will determine lading rates, in other words, the fewer is entrance gateway number, the longer queuing lines will be produced outside terminals.

Following Lithuania's accession to the EU neither ports nor motorways and roads will have customs and border clearances on the internal territories of EU. However as of July 1, 2004 a new ISPS Code (International ship and port facility security code) is to come into effect. Therefore at port terminals the number of clearance points will retain its importance.

CTU arriving for clearance intensity will be:

$$\lambda = \frac{I_p}{\Delta t_p}, \quad (27)$$

here: I_p – number of departing CTU vehicles (aboard a ro-ro ferry from terminal); Δt_p – time interval for major clearance of CTU.

Clearance time per CTU in a check-point is set as t_i . Then average clearing time per CTU in a check-point will feature:

$$t_a = \frac{\sum_{i=1}^K I_i \cdot t_i}{\sum_{i=1}^K I_i}, \quad (28)$$

here: I_i – number of checks at a check-in point over the period of time Δt ; t_i – average check-in duration; K – number of checks-in at a check-in point.

Then average CTU clearing time at a check-in point will be:

$$W = W_q + t_a, \quad (29)$$

here: W_q –average queuing time per CTU at the check-in point.

With regard to the CTU lading and freight type, and clearing facilities and technologies available at the check-in point, clearing time should take 5 to 30 minutes. Check-in points on terminals should be considered as single-track mass processing structure. Under processing intensity rating as λ , the processing time intensity can thus be rated based on the exponential law, as follows:

$$\mu = \frac{l}{t_a}, \quad (30)$$

here: l – number of check-in points at the terminal.

Then we have average clearing time per CTU as below:

$$W = \frac{\lambda t_a^2}{l(l - \lambda t_a)} + t_a. \quad (31)$$

Under condition $W \leq T$, we have:

$$l^2 - \lambda t_a l - \frac{\lambda t_a^2}{T - t_a} \geq 0. \quad (32)$$

Here the required number of check-in points per ro-ro terminal will be:

$$l \geq \frac{\lambda t_a \left(1 + \sqrt{\frac{l+4}{T-t_a}} \right)}{2}. \quad (33)$$

Average number of CTU queuing for clearing at a single check-in point will read:

$$L_q = \frac{\varphi}{(1-\varphi)l} - \varphi^2. \quad (34)$$

Therefore for to establish appropriate number of check-in points it is necessary to evaluate average number of CTU queuing for clearing at a single check-in point L_q .

Inadequate number of check-points will lead to failed operation when all vehicles arriving at terminal at peak hours will fail the due clearance what will consequently call for ship's delay and give rise to break scheduled depart /arrival of the ferry, particularly if there is an immediate next ship call at the same pier right after departure of the first one.

Number of CTU to use parking spaces $S_{s(\max)}$ will depend on:

- ship's arrival time at the terminal t_i ;
- number of CTU vehicles discharged from every ro-ro ferry received i ;
- average time (term) for CTU parking (guarding) at the terminal t_s ;
- CTU likely to use parking spaces on the terminal i_s .

Therefore number of CTU likely to use terminal parking facilities may be written as follows:

$$S_{s(\max)} = \sum_j i_s i_j. \quad (35)$$

Here, the summation is based on all j whose $t_i - t_s < t_j < t_i$.

As a primary value $S_{s(\max)}$ maximal S_{s_i} is taken to be set up through expert research within period of time t_1 to $t_n + t_s$, where n means number of arriving ships.

Thus:

$$S_{s(\max)} = \max_{1 \leq i \leq n} \{S_{s_i}\}. \quad (36)$$

Separate parking spaces for CTU arrivals and departures are provided, or alternatively, separate parts on same parking grounds are utilized at ro-ro terminals. Taking into account that every single freight consignor/consignee (CTU) require separate parking space, we further have to assume that any possible extra-dimension freight might occupy several parking spaces. Then:

$$n_{ak} = S_{s(\max)} (1 + P\{n_r > m_r\}), \quad (37)$$

here: $P\{n_r > m_r\} = \beta_r$ – extra-dimension freight part.

Then average number of CTU will be:

$$n_r = \frac{\sum \gamma_r}{\sum S_i}, \quad (38)$$

here: γ_r – number of parking spaces intended heavy-duty vehicles; S_i – number of CTU likely to use parking facilities.

Number of parking spaces is important both to those CTU vehicles that await boarding the ship and for the debarking ones, assuming that part of the departing vehicles enter terminal and undergo clearing prior to ship's arrival, therefore a certain number of storage (accumulating) facilities is required at the terminal. That would enable extra overloads at the entrance gateways and check-points before boarding the ship and departure.

5. Practical Implementation of Ro-Ro Transportation Research Methodology and Models of Factors Affecting Ro-Ro Freight

Amongst the ro-ro facility operations on the Baltic the leaders are Swedish and German ports. Based on the statistical data from ro-ro line service Zasnitz (Germany) – Treleborg (Sweden) and the mathematical statistical methods as presented above, mathematical modeling of freight flows and flow forecasts have been derived for 11-year term ahead.

Freight flow rate forecasting and intensity estimates have been based on the data from these Ports as their statistics has been provided in different way from that used by other ports, i.e. they base ro-ro statistics on the CTU (cargo transport unit) data, whereas majority of ports present their data estimated in tons which fails to reflect the current cargo flow range.

The freight flow forecast is delivered for 11 years ahead, i.e. until 2012 in order to compare and verify the cargo flow estimates and intensity calculations based on the above methodology with those received from the Statistical department of Port of Zasnitz (Germany). The statistical estimates conducted by the statistical department have been based on the special program, yet no information is available on the forecast methods.

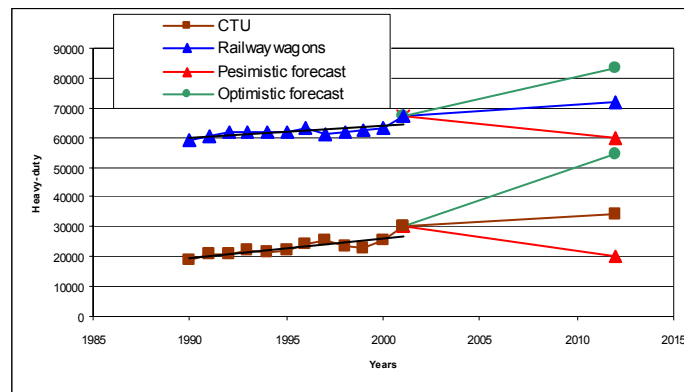


Fig. 3. Forecasted freight flow rates

In freight forecast it is essential to determine possible inaccuracies and consider them when designing and developing ro-ro terminals and shipping lines.

Freight flow research will allow not only viewing the status quo of the freight flow situation yet may provide estimated potential freight flows in future with due consideration of possible inaccuracies and potential for establishing cargo flow stability.

The results are compared based on the methodology presented in

the dissertation and data administered by statistical department.

Difference of the results in 1,25–1,52 %. It is obvious that estimated forecast is slightly different. Meanwhile the actual current freight flow turns to be lower by 0,5 % than that derived by statistical department. Therefore flow forecast methodology can be applied for freight flows forecasts.

Ro-ro flow intensity ratings change in the course of year, influenced by seasonal impacts (winter – off-season, end of the year, eves of popular seasonal holidays). It is therefore important to take this into account.

For instance, take a possible case when CTU and railway cars are transported in-between German and Swedish ports. For to ensure the continuous transit some disadvantageous probabilities have to be considered like:

- Technical damages and hindrances at the terminals;
- Adverse meteorological conditions;
- Operational and organizational hindrances etc.

Given the known values of freight rate forecasted and in order to ensure the proper and due deliveries it is inevitable to find out the intensity rate E and number of ships operated.

Freight flow intensity to be calculated based on the formula:

$$E = \frac{1}{P_{vez}}, \quad (39)$$

here: P_{vez} – freight delivery reliability factor.

Based on the methodology for freight intensity calculation we are able to produce freight flow intensity values, and optimum number of ro-ro ferries required for optimum operation of the shipping line, and the required technical parameters of terminals.

Based on the freight flow intensity calculations and having compared thereof with the actual situation at Ports of Zasnitz and Trelleborg it has been established that an optimum and efficient line operation would require 3 ro-ro ferries. This complies with the real

situation in the above Ports as according to the statistics, overall ferry load varies between 80–95 %, i.e. freight flows are processed free of any hindrances.

So that to ensure continuous freight processing and boarding operations seven entrance gateways are required at the terminal. Less number of terminal entrance gates would give rise to traffic congestions outside terminal gate which in its turn will bring negative impact on terminal operation during ship boarding.

Having compared the actual situation at ro-ro terminal with that proposed number of gateways it has been found that current entrance gateways are fewer. Surveys showed that that normally during peak hours the number of CTU queuing to enter the terminal amount up to 2–4 vehicles per line. However when CTU arrive at the terminal on due time no operations are obstructed and ships is processed for boarding without hindrances.

Should CTU arrive at the terminal later, ship boarding would be affected thus in order to avoid this obstacle the number of terminal access passes have to reach 7 gateways, what is sometimes exercised by making use of additional access gates from other shipping lines at the terminal.

For optimum process of a particular freight flow over 3 hours they require 2 check-points, this way it is possible to avoid long queuing at the customs points and speed up customs clearance without further impact on ship's departure.

Through comparison of the existing number of check-points with that estimated by Zasnitz port department it is obvious that present number of check-points exceeds the optimum required number: there are four of them. This is excess number (proven by way of experiment) as not all the points are subject to full work load. Estimated optimum number of check-points that should ensure proper processing of freight could be lessened.

Based on the expertise, weight coefficients have been worked out and on the basis of complex assessment of factors affecting ro-ro transport, road and rail freightage have been evaluated.

Based on the complex evaluation and consideration of factors to

affect ro-ro freight we may draw a conclusion that ro-ro transport is likely to boast more advantages in respect of motorways transport given that the delivery routes are similar in distances. The factors of freight charge, delivery time and safety account for the largest weight coefficient.

The new ISPS Code has confronted a negative reaction from both port terminals and shipping line operators who merely approach the new code as extra waste of time at ro-ro service lines. This will be caused by additional checks at ro-ro terminals. For motorways these procedures will not apply therefore we can maintain that delivery time factor in ro-ro freightage may slightly increase although under due organization of terminal operation and appropriate facilities available (required number of entrance gateways, proper number of check-points etc.) that impact will be minimal. Meanwhile in the road transport an imposed stringent work schedule requirements and possible increase in petrol rates might impair the transportation conditions.

Through application of the complex assessment of factors affecting ro-ro industry it is possible to achieve rather accurate comparison for the existing ro-ro shipping lines and apply the method in development of new lines and optimization of the operation of existing lines which allows to set out clear advantages of one transport industry in respect to the another industry.

Yet the complex assessment model of factors will be subject to certain restriction. The model can be applied and weights are correct if there are no obvious and considerable change in factor weights which is dependent on the internal changes of that transport type. For instance, in deliveries of expensive and urgent goods, the weight coefficient is likely to shift in favor of some or another transport.

The expertise carried out has excluded the expensive and extra urgent deliveries since these data would distort the actual situation in the freight market. Therefore for assessment of ro-ro freight in this respect it is necessary to undergo additional expert investigations which would cover these specific cargoes.

Conclusions

1. Research on the basic ro-ro shipping lines on the Baltic showed that ro-ro freight are subject to numerous negative factors whose impact is related not only to the transportation itself yet also to port terminal operation and overall business environment which generate ro-ro shipments.
2. Internal competition inside ro-ro industry and in respect to other transports depends on the impact from equal factors to the rival transports, and as the main competition indicator total ratio of factors is featured. The lower is the relative value the higher turns to be the factor of competitiveness.
3. The revised forecast methods proposed in the dissertation by the Author allow to avoid considerable forecast inaccuracies under the critical freight flow situation.
4. Ro-ro freight forecast methodology may be applicable for ro-ro flow forecasts. The accuracy has been verified in comparison to the data from Zasnitz Port statistical department. It has been established that forecast results differ in 1,25–1,52 %, meanwhile the actual current freight flow turns to be lower by 0,5 % than that forecasted.
5. Ferry boarding and lading time minimization at port as offered by the Author of the dissertation enables to reduce time factor in 5–25 %, dependent on the respective terminal and in compliance with the new ISPS Code effective as of July 1, 2004.
6. A complex assessment model of factors affecting ro-ro freight has been introduced that covers the impact of both subjective and objective factors (freight charge, delivery time, safety, possibility to change the sailing route, insurance, banks and other issues) on ro-ro transportation. Such model provides proper evaluation of the current ro-ro environment and situation and determines the impact of negative factors and potential for reduction thereof in comparison to other transport industries.
7. Through application of the complex assessment model of factors affecting ro-ro freight an experimental complex evaluation of ro-ro freight by a shipping line and by motorways have been performed.

It has produced a factor correlation coefficient in ro-ro industry varies between 0,85–0,92, and freight charge account for the largest part of factor weights (0,32–0,34).

8. During verification of model efficiency it was found that in evaluation of transports other than ro-ro, part of factors are excluded from evaluation as they simply do not exist.
9. The introduced complex evaluation model can be successfully applied while re-structuring of ro-ro shipping lines and developing the existing facilities, by due evaluation, minimization and optimization of separate components in ro-ro shipping; it can further be adapted for other transport industries (inland waterways, combination transport etc.)

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About the author

Ričardas Maksimavičius was born in Klaipeda on the 5th of January, 1975.

Master of science in Port management, faculty of Marine technology, Klaipeda University, 1999.

First degree in Navigation, Klaipeda University, 1997

Chief officer on the ro-ro/railway ferry “Klaipeda” of the “Lisco Baltic Service”, assistant at Shipping department of the Faculty of Marine technology of Klaipeda University.

Šiuo metu Lietuvos linijinės ro-ro laivybos kompanijos, susidurdamos su didele konkurencija ro-ro laivybos srityje, stengiasi išlaikyti savo pozicijas, užimti ir įsisavinti naujas ro-ro laivybos rinkas. Tačiau reikia paminėti, kad glaudus bendradarbiavimas su kitomis transporto rūšimis ir ro-ro terminalais ne visada pasiekiamas, o tai sustiprina veiksmų darančių įtaką gabenimui, poveikį ir apsunkina jų kompleksinį vertinimą bei mažina tokių vežimų patrauklumą ir atitinkamai ro-ro krovinių srautus.

Problemų aktualumas. Nemaža ro-ro laivybos linijų dalis tik atsidariusios būna priverstos nepraėjus ilgesniam laikui užsidaryti kaip neperspektyvios, nes nesugeba pritraukti pakankamų krovinių srautų, dėl daugelio priežasčių, tokių kaip netinkamas privalumų, trūkumų, grėsmių įvertinimas ir galimybių pervertinimas, nepakankamai ištirtas krovinių srautų intensyvumas ir optimistinės prognozės, veiksmų darančių įtaką ro-ro vežimams, nevertinimas ar nevisiškas įvertinimas. Taigi disertacijoje nagrinėjama tema **aktuali** ne tik kuriant naujas ro-ro laivybos linijas, bet ir plėtojant jau esamas ar net atkuriant ankstesnes ro-ro laivybos linijas, taip pat ir siekiant padidinti konkurencingumą su kitomis krovinių vežimo rūšimis.

Disertacijos tikslas-teoriškai ištirti ro-ro vežimų principus ir įvertinti veiksmus, darančius įtaką ro-ro vežimams, bei ro-ro vežimų plėtros ir optimizavimo galimybes, jų pagrindu sukurti veiksmų vertinimo modelį ir atlikti jo eksperimentinį taikymą.

Pagrindiniai uždaviniai:

- nustatyti objektyvius ir subjektyvius veiksmus ir jų poveikį ro-ro linijinei laivybai;
- sukurti ro-ro vežimų kompleksinį vertinimo modelį;
- pritaikyti klasikinius prognozavimo metodus, įvertinant ro-ro vežimų ypatybes ir galimas ro-ro krovinių srautų krizes;
- atlikti praktinį-eksperimentinį tyrimo metodikų ir sukurtų modelių tikrinimą.

Šio darbo mokslinis naujumas:

Patikslinta ro-ro krovinių srautų prognozavimo metodika, nustatyti veiksniai įtakoiantys ro-ro vežimus ir sudarytas veiksmų įtakojančių ro-ro vežimus Baltijos jūroje kompleksinis vertinimo modelis, ro-ro

laivybos linijų perspektyvumui pagrįsti. Atliktas ro-ro keltų pakrovimo uoste laiko minimizavimo teorinis pagrindimas užtikrinant reikiamą praleidimo vartų į terminalą, kontrolės postų ir stovėjimo aikštelių kieki.

Disertacijoje ginamos šios pagrindinės nuostatos:

- ro-ro vežimų ypatybių Baltijos jūroje tyrimų metodų taikymas;
- pagrindiniai veiksniai, įtakojančys ro-ro vežimus Baltijos jūroje;
- objektyvių ir subjektyvių veiksnių įtakojančių ro-ro vežimus Baltijos jūroje kompleksinis vertinimo modelis ir suminio kriterijaus išraiška vežimų tikslingumui įvertinti;
- patikslinta krovinų srautų prognozavimo metodika ro-ro laivybos linijų perspektyvumui pagrįsti, įvertinant krizinį krovinų srautą;
- ro-ro keltų pakrovimo laiko uoste minimizavimas, atsižvelgiant į naujai įsigaliojusį laivų ir uosto įrenginių apsaugos kodeksą (ISPS Code).

Darbo praktinė reikšmė. Disertacijoje pateikti veiksnių įtakojančių ro-ro vežimus modeliai galėtų būti taikomi, kuriant naujas, plėtojant jau veikiančias ir atnaujinant uždarytas ro-ro laivybos linijas, atsižvelgiant į objektyvius ir subjektyvius veiksnius įtakojančius ro-ro vežimus. Minimizuojamas ro-ro keltų pakrovimo laikas uoste.

Darbo aprobacija. Pagrindiniai disertacijos teiginiai aprobuoti 5 mokslinėse konferencijose ir paskelbti 9 moksliniuose leidiniuose.

Apimtis ir struktūra. Disertaciją sudaro įvadas, penki skyriai, svarbiausios išvados, literatūros sąrašas. Disertacijos tekstą sudaro 128 lapai. Darbe yra 15 paveikslų, 12 lentelių, 6 priedai. Literatūros sąrašą sudaro 110 publikacijų.

Išvados

1. Išnagrinėjus pagrindines ro-ro laivybos linijas Baltijos jūroje nustatyta, kad ro-ro vežimai yra veikiami daugelio neigiamų veiksnių, kurių poveikis priklauso ne tik nuo pačių vežimų, bet ir uostų terminalų darbo bei aplinkos, kurioje plėtojami ro-ro vežimai.
2. Ro-ro vežimų konkurencingumas tarpusavyje ir su kitomis

krovinių gabenimo rūšimis priklauso nuo vienodų veiksnių poveikio konkuruojantiems gabenimams, o pagrindinis konkurencingumo rodiklis yra suminių veiksnių santykis. Kuo yra santykinis dydis mažesnis, tuo didesnis konkurencingumas.

3. Disertanto pasiūlytas ro-ro krovinių prognozavimo metodų patikslinimas leidžia išvengti didesnių prognozavimo paklaidų esant krovinių srautų krizei.
4. Pritaikyta ro-ro krovinių prognozavimo metodika yra tinkama prognozuoti ro-ro krovinių srautus. Tikslumas patikrintas lyginant su Vokietijos Zasnico uosto statistikos departamento duomenimis. Nustatyta, kad prognozių rezultatai skiriasi 1,25–1,52 %, o dabartinis krovinių srautas yra 0,5 % mažesnis nei prognozuojamas.
5. Disertacijos autoriaus pasiūlytas keltų krovos uoste laiko minimizavimas, leidžia sumažinti laiko veiksnio įtaką, atsižvelgiant į nuo 2004 m. liepos 1 d. įsigaliojusį laivų ir uosto įrenginių apsaugos kodeksą, nuo 5–25 %, atsižvelgiant į ro-ro terminalą.
6. Pasiūlytas veiksnių, darančių įtaką ro-ro vežimams, kompleksinis modelis, apimantis objektyvių ir subjektyvių veiksnių (krovinio vežimo kainos, laiko, saugumo, galimybės pakeisti plaukiojimo maršrutą, draudimo, bankų, kitų veiksnių) poveikį ro-ro vežimams. Toks modelis padeda įvertinti esamą ro-ro vežimų aplinką, nustatyti neigiamų veiksnių įtaką ir jų mažinimo galimybes, lyginant su kitomis vežimų rūšimis.
7. Taikant veiksnių, darančių įtaką ro-ro vežimams, kompleksinį modelį atliktas eksperimentinis vežimų ro-ro laivybos linija ir sausumos keliu kompleksinis vertinimas. Nustatyta, kad veiksnių koreliacijos koeficientas gabenant ro-ro laivais svyruoja nuo 0,85–0,92, o didžiausias veiksnių svoris tenka vežimų kainai (0,32–0,34).
8. Tikrinant modelio veiksmingumą nustatyta, kad vertinant kitokius nei ro-ro krovinių vežimus, dalis veiksnių yra nevertinami, nes jie neegzistuoja.
9. Sukurtas kompleksinis vertinimo modelis gali būti sėkmingai taikomas atkuriant ro-ro laivybos linijas bei plėtojant esamas, įvertinant bei minimizuojant ir optimizuojant pavienius ro-ro laivybos linijų elementus, taip pat jis gali būti adaptuotas kitoms vežimo rūšims (vidaus vandens keliams, mišriems vežimams ir t. t.).

Ričardas Maksimavičius
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Saulėtekio al. 11, LT-10223 Vilnius-40
Spausdino UAB „Sapnų sala“, Moniuškos g. 21-10, LT-08121 Vilnius