MODEL OF RIVER COORDINATION MULTIMODAL LOGISTICS CENTER

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Stručni članak

SUMMARY

The advantages of inland water transport in terms of environmental impact, transport efficiency make it very attractive for the main segments of multimodal/intermodal transport, but at the same time significant efforts are needed to ensure its good interaction with other modes of transport for the remaining modal shares of the transports. The work proposes a concept for the construction of Coordination Logistics Centers on the basis of river ports, which can provide good solutions for a more complete use of the capacity of inland water transport, ensuring interaction with rail and road transport. The centers need the development of specific models for the organization of work, including in terms of forecasting hydrological conditions that directly affect navigation conditions and cargo turnover in river ports. The proposed ARIMA method is suitable for forecasting hydrological conditions. On the basis of statistical data, a forecast of these conditions was made using the method for a specific port on the Danube River in Bulgaria.

Key words: *inland water transport, river multimodal coordination center, statistical methods for forecast of the water level*

1. INTRODUCTION

The advantages of inland water transport in terms of environmental impact, transport efficiency, etc. makes it very attractive for the main segments of multimodal/intermodal transport, but at the same time significant efforts are needed to ensure its good interaction with other modes of transport for the other modal shares of transport.

Like other modes of transport, inland waterway transport has to deal with meteorological phenomena affecting navigational conditions and inland waterway infrastructure. Along with this, good coordination with other modes of transport should be ensured, especially at low water levels. Building a system of port-based multimodal coordination centers can provide good solutions for a more complete use of inland waterway transport capacity.

2. EXPOSITION

Preferences regarding the geographic location of logistics companies, the impact of rent and access; proximity (access) to highways, ports, railways, waterways and business parks is the reason for the presence of a large number of industries and logistics companies in the perimeter of ports [12].

Considering operational process innovation, stakeholder benefits, employability, customer satisfaction, and the development of inland regions, regional intermodal logistics centers can provide great opportunities [7].

Many studies have advocated a shift in modal use, supporting the shift of automotive logistics to rail and inland waterways as a development opportunity [14, 8, 3].

The case of Croatia, where the country is developing intermodal networks for greater logistical efficiency, is discussed in [5].

There are other opportunities presented that can stimulate the development of river logistics, and in a study [4], the problem of intermodal land and water transport logistics in the Yangtze River region is reviewed, based on the method of two-level programming, with a built-in model to optimize the layout of the area under the condition of flow of goods in both directions (water-land and land-water). The model includes the optimized selection of ports as intermodal transport hubs and the determination of all ports after construction from the perspective of the logistics planning department, and the optimized selection of water-land intermodal transport routes and the determination of the volume of goods between the routes. The example reveals that the layout optimization problem in the Yangtze River Basin under the condition of two-way flow of goods can be modeled by two-level programming, where a two-way route method is presented with the aim of higher productivity and lower cost of river logistics. In [8] a study is made where similar practices are used to ensure more efficient inland water transport. In [6], a decision support model for service network design in intermodal barge transport is presented. The model determines optimal transport routes for two-way services between a large seaport and several inland ports located along a single waterway

According to [8], the main challenge to be overcome is the change to transform the logistics chain as an intermodal network with several participants.

In [13] it is stated that nowadays it is a challenge to develop greener logistics by balancing the logistics modes of transport, reducing road freight transport and switching to other modes. Inland waterway transport in this context stands out as it is the most sustainable transport in logistics, besides having lower costs. Using a systematic approach, the main research challenges and opportunities are highlighted in various articles in the field of river logistics. The first group of research challenges lies in the evolving relationship between transport geography and logistics activities. The next set of research challenges aims to promote efficient operations in inland waterway transport: developing a system model for it, integrating operational planning systems and analyzing clustered networks. A third group of research efforts is aimed at shippers and receivers who use the intermodal transport chain to send or receive their goods: further development of models that integrate intermodal transport solutions with supply chain solutions and create green chains for supplies. The fourth set of research challenges concerns the problem area of external cost calculations. Finally, it is stated that detailed freight transport time series data are needed to support future research directions.

Consolidation of freight flows can improve the efficiency of multimodal/intermodal operations. Domestic terminals can cooperate to create tighter cargo flows and achieve economies of scale. In this way, the attractiveness of multimodal/intermodal barge transport can be improved.

In [1], alternative bundling strategies for the transport of container barges in the port of Antwerp are analyzed by simulating four alternative scenarios for the construction of a packet network in the port area with respect to the operational characteristics of the network.

In [2], three main models were developed to create a comprehensive framework for evaluating intermodal transport policies: a multimodal freight model (NODUS), a discrete event simulation model of the inland waterway network and its terminals (SIMBA) and the LAMBIT model, supporting location analytics for Belgian intermodal terminals. The combination of the three models creates a decision-supporting system that allows the simulation of policy measures to support the intermodal transport industry and the prediction of possible problems in the freight infrastructure network. The effectiveness and sustainability of policy measures in terms of modal shift, external costs and capacity constraints can be analysed.

Attention to multimodal/intermodal transport, along with economic efficiency, is based on the desire to reduce the externalities of transport and thus arrive at a more sustainable transport system. In the literature, the most important external transport costs are [4]: accidents; noise; Air Pollution; climate change; traffic jams. Marginal external costs of transport activities depend strongly on various parameters such as fuel type, location (urban, inter-urban, extra-urban), driving conditions (peak, off-peak, night) and vehicle characteristics (EURO standards). This explains the diversity in results that is sometimes seen when looking at different studies of external transport costs. According to [10], water transport makes it possible to achieve modern high-capacity freight transport without much harm to the environment, which means that it pollutes much less than rail and road transport.

Carbon dioxide emissions from road transport and multimodal/intermodal container transport can be found in [9].

In [11] it is stated that despite the growing needs of freight transport, there are concerns that the planning tools available today will be insufficient to provide the system-wide view that is needed to study all modes of transport, including multimodal/intermodal. Many existing tools are either modal-oriented or too microscopic in scope. No comprehensive tool considers the performance level of the entire system – an important consideration because of the many interdependencies between resources. In some cases, optimizing only a certain component of the transportation network can lead to the non-optimization of the entire transportation system. The study presents a prototype of a virtual intermodal transport system (VITS); it simulates the movement of goods in all types at the state level. Detailed sub-models can be designed to allow planners to analyze the overall impact of decisions made on critical transport resources such as ports and their links.

There are many different analytical models used to determine modal choice, as well as factors that influence decision making. However, it is important to keep in mind that there are also various trade-offs between these factors and that decision-making depends on different actors such as shippers, consignees, carriers and logistics service providers.

Given the fluctuations of the water level and the need for effective interaction of the modes of transport, in order to increase the modal share of inland waterway transport, it is necessary to build a unified information environment and organizational structure that can ensure the planning of the interaction of the different modes of transport. The format can be Coordination multimodal logistics centers built on the basis of the river ports or on the basis of an independent enterprise. An example principle of a structural diagram of a Coordination Multimodal Logistics Center is shown in fig. 1.

The structure of the centers include management, production and supply subsystems arranged in a hierarchical sequence. One of the separate units of the logistics chain for the transportation of goods is the production system.

With its management subsystem, the center will ensure optimality in the operation of river and other types of transport. It is the analytical center for strategies and logistics coordination. The management system performs the integrative "management" function with input of internal and external environment.

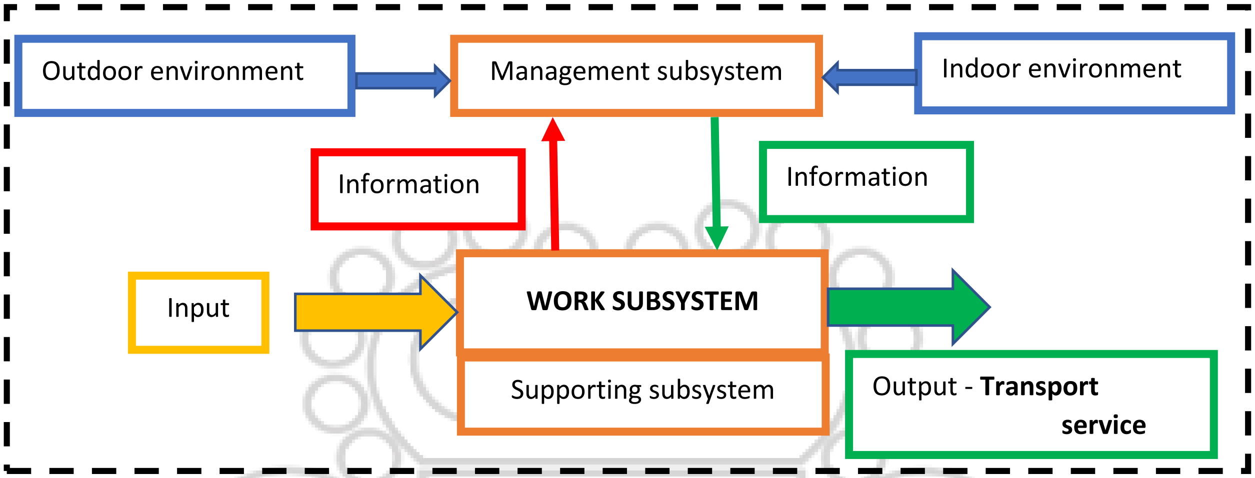

Fig. 1. Principle of a structural diagram of a river coordination multimodal logistics center

The production subsystem is the very process of transport production of the types of transport. In it, several internal blocks are clearly separated: technical, these are the functioning permanent devices and rolling stock, and technological in a narrow sense, this is a set of rules defining the successive operations and processes related to the execution of the transports (the rules for the transport of goods, tariffs, technical operation of transport, loading and unloading operations, etc.). In practice, the transport process is the joining of the technical and technological parts into a functioning complex by using "human activity" - the physical efforts and knowledge of the staff. The input of the production system is energy, materials, human resources, etc., and the output is the transportation service.

The security subsystem creates technological and technical conditions for the operation of the production system. It supports production (repairs, maintenance, etc.).

Along with this, especially in the case of international messages passing through the territory of the country, the level of interaction of the organizations representing the different types of transport in the transport hubs and the absence of a system of logistics centers providing the necessary level of this interaction is insufficient.

The reduction of logistics costs in the implementation of multimodal/intermodal transportation with the use of coordination logistics centers in river ports will be determined by the following factors:

- closer interaction with customs authorities in the coordination multimodal logistics center, which will lead to a reduction in non-production downtimes of ships and other types of vehicles;

- coordination of working hours of the port, customs authorities and organizations of other modes of transport;

- speeding up the passage of export-import and transit cargo through the ports, reducing the volume of stored cargo, which reduces the need for warehouse structures and increases the throughput of transshipment complexes.

In fig. 2 the main socio-economic and geopolitical effects of the development of the Danube system of coordination multimodal logistics centers are indicated.

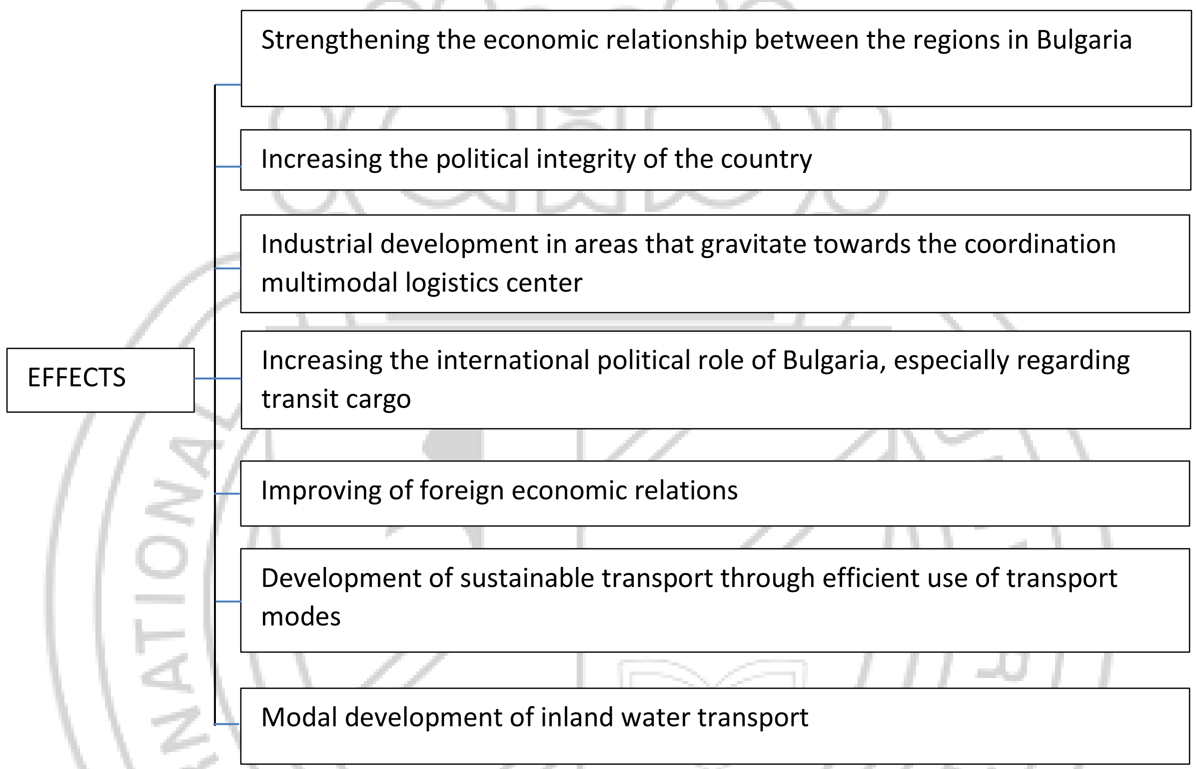

Fig. 2. The main socio-economic and geopolitical effects of the development of the Danube system for coordination of multimodal logistics centers

In the coordination modeling framework, we can distinguish three main layers: physical; planned; contractual.

The processes in the physical layer are mainly transport, processing and storage.

In the planning layer, the systematic ordering, distribution and coordination of physical processes is carried out by measuring efficiency according to certain indicator(s) (minimum costs, minimum delay, maximum volume, minimum capacity, waste, etc.).

In the contractual layer are the processes related to trade negotiations, reciprocal agreements, etc.

The results of the different activities in the layers are interconnected; contracts define the conditions under which planning processes are carried out. At the physical layer, capacity or other resources are often limited, hence the need for planning. The commercial contract and planning activities determine the execution of the physical activities.

In operational activity, the interaction of these three layers must be studied and optimal solutions developed.

Modeling and Analysis of Coordination Challenges

Modeling coordination challenges

- identification of central processes for which there are symptoms or complaints and their inclusion in the planning layer. A process(es) that affects many many types of processes that are executed by many parties (one-to-many) and a process that is affected by multiple processes that are executed by different parties are identified.
- the actors who perform the planning processes are identified and predominantly contractual structures are modeled by linking these actors to their contracts and objectives. The objectives may be in line with the firm's corporate strategy, such as maximizing profit or minimizing transit or dwell time.
- determine the requirements that are imposed by the contract, for example a time requirement for each planning process;
- identify the necessary information that is needed between physical and planning processes, for example container status or disruptions in transport services.

The constructed model forms the basis for understanding and discussing coordination challenges. It includes: the actors and their often conflicting goals and the interaction of the actors in/between the three layers

Based on a more detailed analysis of the model, opportunities for process improvement can be explored.

Analyzing the coordination challenge using the model

A number of coordination challenges can be identified, but the main ones are:

- conflicting and competing goals among participants and the role of contracts;
- complications due to causal relationships;
- missing or delayed information.

Coordination challenges usually arise from an interaction between these factors.

Coordination challenges also arise due to problematic interactions between parties within a layer or between different layers. The theory predicts that these interactions are characterized by conflicts of interest. A conflict of interest can be resolved by contracts where the gap between expectations and efforts is closed by monetary compensation. Problems arise where interactions are required and conflict arises, there is an interest that is not offset. The parties' interests are essentially materialized into physical processes through the objectives of the planning processes. Therefore, a crucial step is to focus on the effects of negotiation processes on planning processes. Conflicts of interest can be observed directly in the interaction (e.g. the need for fast delivery) or in the form of competition between parties (e.g. logistics companies in the same region). A framework for modeling and analyzing coordination challenges from an economic point of view is used performance indicator (KPI) by forming different types of coordination mechanisms. For example, a framework with a broad view of the countries that interact the most, which treaties bind them, what their goals are, and how those goals and treaties align with planning processes. Having a broader and more complete view can help understand contracts and what needs to be done.

Coordination logistics centers for inland waterway transport need the development of specific models in terms of forecasting hydrological conditions that directly affect navigation conditions, cargo turnover in river ports, which affects the operation of ports and the operation of other modes of transport (rail and automobile), by organizing the joint work of the modes of transport and other economic entities.

An example of the need for river level forecasting

One of the problems for inland water transport on the Danube is the low levels, which are the reason for the suspension of shipping. In the presence of a coordination logistics multimodal center, appropriate decisions can be made and coordinated after forecasting the levels: transshipment of the entire cargo or part of it on road or rail transports/or additional use of the barge.

In this forecasting of the river level is of utmost importance. The analysis of the time series for the river levels allows to understand the development of the processes and the possibility of their effective management. By applying appropriate statistical methods, future process values can be predicted and appropriate decision-making strategies applied. Statistics offers many methods for studying and modeling time series. Building a mathematical model of the time series is based on finding a formula/formulas that most accurately reflect the change of the series over time. Due to the specificity of the data, different time series modeling methods are suitable for the study of hydrological conditions. These methods include classical time series models, Autoregressive Patterns (AP), Moving Average (MA), Autoregressive – Moving Average (ARMA), autoregressive, integrated, moving average (Autoregressive Integrated Moving Averages (ARIMA)).

Three parameters – p, d and q – were used to build the ARIMA models . The autoregressive element p is the impact of data from p previous moments in the model. The integrated element d is the trend in the data, the element q indicates how many terms are used to smooth out small fluctuations using a moving average.

As an example, the ARIMA models will be applied to determine average weekly levels of the Danube River near the town of Svishtov. The product program is SPSS .

The model proposed by the system is ARIMA (1,0,1), Table 1.

Table 1. Type of ARIMA model

Model Description

			Model Type
Model ID	Level Svishtov	Model _1	ARIMA (1,0,1)

The confidence interval guaranteed with probability γ =0.95 of the error of autocorrelations and partial autocorrelations for 24 lags can be reported from Fig. 3.

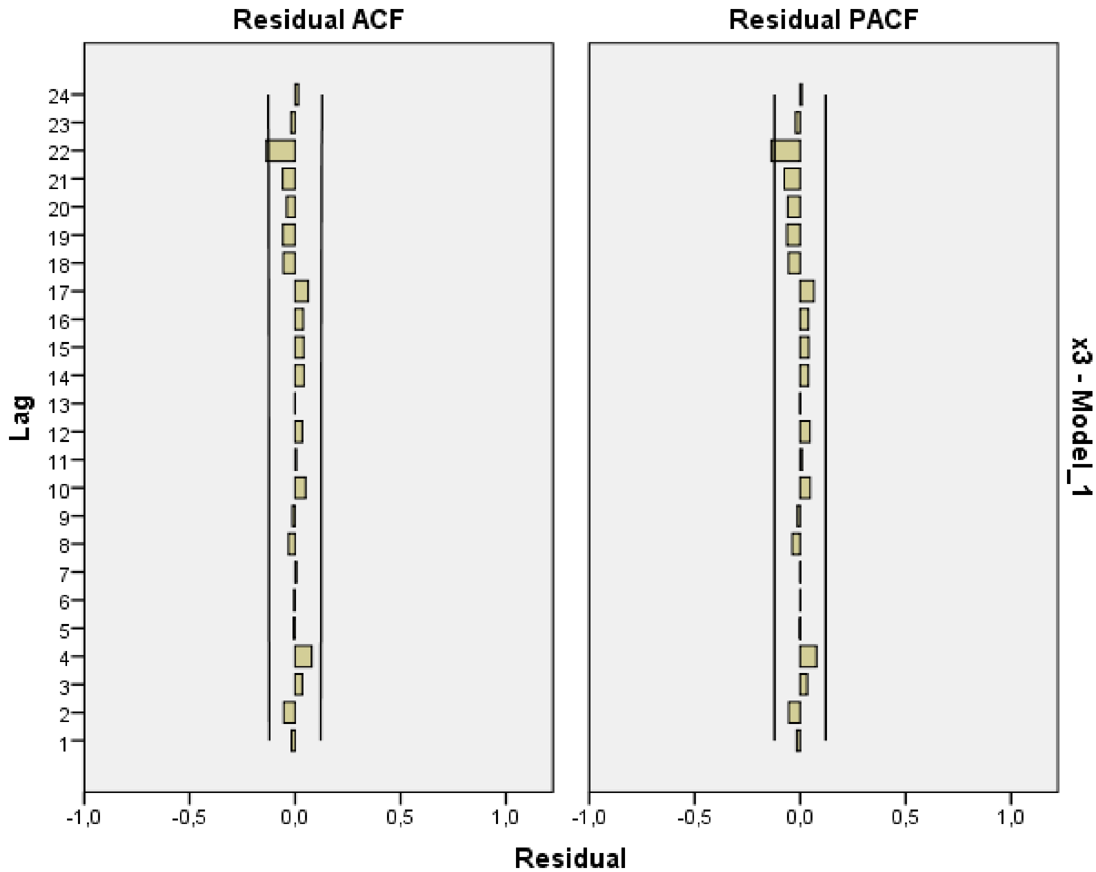

Fig. 3. Confidence interval guaranteed with probability γ =0.95 of the error of autocorrelations and partial autocorrelations for 24 lags

In fig. 4 presents actual measured values, approximated values according to the model, predicted values and interval estimates of the approximated and predicted values.

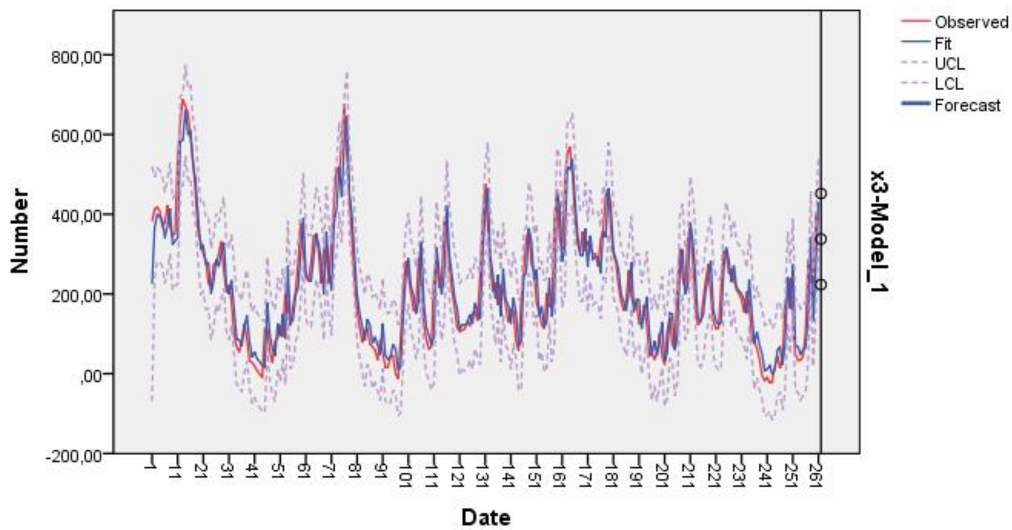

Fig.4. Actual measured values, model-approximated values, predicted values, and interval estimates of approximated and predicted values

In the table 2 shows the main characteristics of the model, including the coefficient of determination.

Table 2. Table with main characteristics of the model, including the coefficient of determination

Fit Statistics	Mean	SE	Minimum	Maximum
Stationary R-squared	,847	.	,847	,847
R-squared	,847	.	,847	,847
RMSE	58,739	.	58,739	58,739
MAP	87,841	.	87,841	87,841
MaxAPE	10716.380	.	10716.380	10716.380
MAE	45,367	.	45,367	45,367
MaxAE	197,687	.	197,687	197,687
Normalized BIC	8,210	.	8,210	8,210

In Table 3 are present statistical estimates of the model, including the Normalized BIC coefficient.

Table 3. Table with statistical estimates of the model, including the Normalized BIC coefficient

Model Statistics

Model	Number of Predictors	Model Fit statistics		Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Normalized BIC	Statistics	DF	Sig.	
Level Svishtov-Model_1	0	,847	8,210	7,568	16	,961	0

Predicted level for the first week of 2023: 337, 80 cm.

Two more models are being developed analogously: Model - ARIMA(2,0,1) and Model - ARIMA(1,0,2) .

In the Table 4 the summary results of the three models are indicated.

Table 4. Summary results of the considered models.

Model/Features and Forecast	Coefficient of determination	Normalized BIC coefficient	Forecast/ level, cm
ARIMA(1,0,1)	0.847	8,210	337.80
ARIMA(1,0,2)	0.847	8,231	341.17
ARIMA(2,0,1)	0.847	8,232	341.65
ARIMA(1,1,1)	**0.839**	**8,256**	**362.10**

The forecast level for the level of the river near the town of Svishtov for the first week of 2023 is 362.10 cm.

3. CONCLUSION

The analysis of the literature sources shows the complex interactions between the inland waterway and the other land modes of transport (rail and road), where it is necessary to look for solutions to ensure efficiency in these interactions, both in multimodal/intermodal transports and in transit situations (eg low water levels). Building a system of coordinational multimodal logistics centers based on river ports can provide good interoperability results that can help increase the modal share of inland water transport. Coordination logistics centers for inland water transport need the development of specific models in terms of forecasting hydrological conditions that directly affect navigation conditions, cargo turnover in river ports. The use of statistical forecasting methods allows the planning of shipments from a specific coordination center.

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