THE CONCEPT OF THE AGRO CARGO SUPPLY CHAIN MODEL USING INLAND NAVIGATION

Magdalena **KAUP** [1] , Dorota **ŁOZOWICKA** [2] , Wojciech **ŚLĄCZKA** [3] ,

Agnieszka **KALBARCZYK-JEDYNAK** [4] , Paweł **CHORAB** [5] , Wojciech **IGNALEWSKI** [6]

[1] Maritime University of Szczecin, Faculty of Navigation, Wały Chrobrego 1-2, 70-500 Szczecin, Poland,
email: m.kaup@am.szczecin.pl, https://orcid.org/0000-0002-9384-8144

[2] Maritime University of Szczecin, Faculty of Navigation, Wały Chrobrego 1-2, 70-500 Szczecin, Poland,
email: d.lozowicka@am.szczecin.pl, https://orcid.org/0000-0001-8031-762X

[3] Maritime University of Szczecin, Faculty of Navigation, Wały Chrobrego 1-2, 70-500 Szczecin, Poland,
email: w.slaczka@am.szczecin.pl, https://orcid.org/0000-0003-3265-9726

[4] Maritime University of Szczecin, Institute of Mathematics, Physics and Chemistry, Wały Chrobrego 1-2, 70-500 Szczecin, Poland,
e-mail: a.kalbarczyk@am.szczecin.pl, https://orcid.org/0000-0001-7513-4837

[5] Maritime University of Szczecin, Department of Rescue and Risk Management, Wały Chrobrego 1-2, 70-500 Szczecin, Poland,
e-mail: p.chorab@am.szczecin.pl, https://orcid.org/0000-0001-6595-7450

[6] Zegger Tech Sp. z o.o, ul. Fabryczna 2, 84-200 Wejherowo, Poland

Abstract – Making transport sentences requires taking into account many external and internal factors dependent on changes taking place on the shipping market. The place, time and type of transported cargo, etc., have an impact on the complexity of the transport system structure, which is why it is important to explore the possibilities and create transport optimization models throughout the entire cargo supply chain and analyze issues related to their organization, which affects the safety and reliability of this type of systems. The aim of the article is to present and analyze the concept of the agro cargo supply chain model using inland navigation, in the relations between Poland and the Federal Republic of Germany on the example of the Capital Group OT Logistics S.A. (OTL SA Capital Group). Taking into account the complexity and structure of transport tasks, it is important to look for optimal solutions in the field of transport. Each supply chain model includes only certain selected factors that have a limited impact on the volatility of the transport. It is not possible to build a model that would fully recreate the behavior of the object, with all possible external influences. The article considers the optimization model of inland wheat transport to final consumers, which predicts a constant demand for cereal loads in certain time segments. This model does not provide any rapid domestic fluctuations in demand for wheat at certain time intervals.

Key words – Inland waterway transport, reliability, modeling, supply chain

JEL Classification – L91, C60, Q10

INTRODUCTION

Transport systems consist of means of transport and reloading infrastructure necessary to perform transport tasks, taking into account the place, time and type of technological operations.

Making transport sentences requires taking into account many external and internal factors dependent on changes taking place on the shipping market. The place, time and type of transported cargo, etc., have an impact on the complexity of the transport system structure, which is why it is important to explore the possibilities and create transport optimization models throughout the entire cargo supply chain and analyze issues related to their organization. Modeling of transport systems is aimed at acquiring tools enabling identification of the dependence of the actual transport object, and most of all, its identification allowing to determine the relationship between the values occurring in

the examined system and determining the course of variation of these quantities, which are the subject of research. It represents the mapping of input elements of the system in accordance with the adopted criteria, so that the modeling process obtain the optimal solution.

Inland waterway transports are competitive on many criteria in relation to road or rail transport. Fees for the use of road infrastructure or increase in fuel prices mean that the costs incurred by land carriers are increasing [4], [10]. A wide range of cargo for transport in inland navigation, i.e. dry and liquid bulk, containerized or oversized cargoes, provides the basis for creating supply chain models for individual load groups at fixed directions and sizes of streams and cargo streams.

The important aspect in the analysis of inland transport is to distinguish the specifics of the supply chains of selected group loads, depending on the place of sending and destination, which will determine the reliability level of their realization. Research opportunities which will enable the further integration of inland waterway transport in the intermodal supply chain are identified in [4]. The search for optimal solutions for the functioning of inland transport is one of the areas of scientific research, which is confirmed by the publication [5]. In [14] a model is developed to analyze and compare the transport costs of intermodal inland waterway transport and road-only-transport. In [15] presented characteristics of inland waterway ports in a European context. This paper [16] identifies research opportunities which will enable the further integration of inland waterway transport in the intermodal supply chain. The potential of inland navigation is indicated, measurable benefits and possibilities of use, organizational and legal, economic or technical and technological issues are considered [2]. The article [8] aimed to develop a concept of a promotion policy to be applied by seaport authorities to increase the share of inland shipping in hinterland transport. The aim of the article [9] was to draw attention to the fact that inland navigation services, on the transport market, are a sufficient factor conditioning the existence of waterways. All other factors only stimulate or limit its place in the transport system. Preferential use of natural waterways is the basic constraint that limits their adaptation to changing transport needs. Often, however, in each developed model only some selected factors are taken into account, which have a limited impact on the performance of these transports [1], [3]. The paper [12] presents a proposal for a model of water-rail

fractured transport, on the example of the transport corridor of the Oder Waterway, indicating reloading ports. It focuses on the reliability of the transport system, pointing to the most important factors affecting the timeliness and realization of deliveries. The goal of the paper [13] was to determine whether the various demands of customers for lower logistics costs have an impact on the business processes of Slovenian companies.

This article considers the optimization model of agro cargo transport to end users using inland waterway transport, which predicts a constant demand for cereal loads in certain time intervals (average demand per unit of time).

The aim of the article is to present and analyze the concept of the agro cargo supply chain model using inland navigation, in the relations between Poland and the Federal Republic of Germany on the example of the Capital Group OT Logistics S.A. (OTL SA Capital Group).

1. TRANSPORT RELATIONS OF AGRO LOADS ON THE EXAMPLE OF OTL SA CAPITAL GROUP

AGRO loads are agricultural loads such as cereals, oats, rye, wheat, rape. Cargo transportation can be carried out throughout the year, but it is necessary to take into ac-count factors that have a significant impact on the frequency of inland transport. These are both supply-demand relations as well as difficulties on waterways, including freezing of waterways (seasonality), low water level or closure of hydrotechnical facilities (e.g. Niederfinow hoist) [9].

In the last years, there is a decrease in the transport of agro loads. In 2014, over 90,000 tons of cereals were transported using inland vessels, in 2015 less than 30,000 tons, and in 2016 only 24,000 tonnes.

The main directions for transporting agro cargo from Poland are the Federal Republic of Germany and Russia. Figure 1 presents the areas of their transport, and Table 1 presents the places of loading and unloading, specifying the types of agro cargo [2], [6].

For transporting agro loads, pushed sets and motor vessels with hatch covers (stacked / sliding) are used. The following sets of examples are used to transport agro loads:
- Pusher Bizon + 3 SL 35 m pushed barges around ca. 500 cmb / SL ca. 1,000 - 1,200 t depending on the density of the load and the batch. Example: wheat 75 kg / hl / 1 500 cbm x 0.750 t = 1 125 tons.
- Bizon (e.g. RTC-2) + 40er pushed barge (65 m) ca. 1,000 cmb + 2 pushed barge SL 35 m ca. 500cmb rape bruised grain.

- Pusher (TR 30) + SL 35 pushed barge + 800 t pushed barge (ca. 900 - 1 100 cmb) ca. 950 - 1 000 tons of rape bruised grain.
- Motor vessel type 80 m (Königstein) ca. 1 500 cbm ca. 950 - 1,000 tonnes of rye.
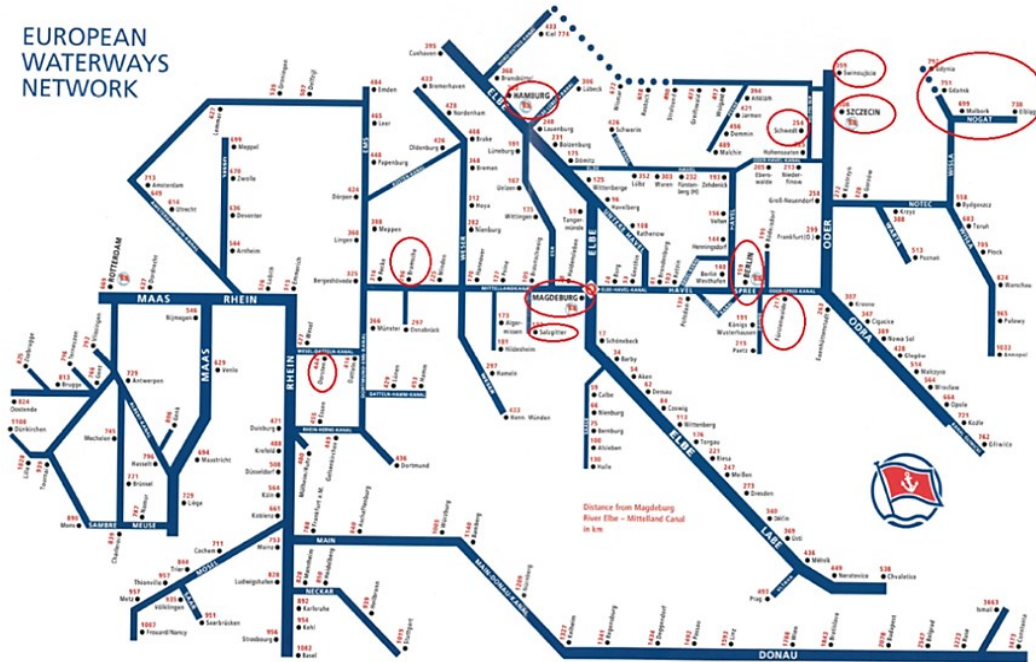- Motor vessel type 500 - 560-700cbm ca. 380 - 480 tons of grain.

Fig. 1. Areas of agro loadings transportation. Source: OT LOGISTICS S.A

Table 1. Transport relations of agro loads [Source: OT LOGISTICS S.A.]

Lp.	Shipping	Unloadong	Cargo
1.	Szczecin	Bramsche	Wheat
2.	Elbląg	Gdynia	Wheat
3.	Elbląg	Gdańsk	Wheat
4.	Berlin Spandau	Vahldorf	Wheat
5.	Schwedt	Berlin Spandau	Wheat
6.	Fürstenwalde	Dorsten	Wheat
7.	Schwedt	Magdeburg	Rape
8.	Schwedt	Vahldorf	Rape
9.	Stepnica	Magdeburg	Rape
10.	Stepnica	Vahldorf	Rape
11.	Magdeburg	Spelle	Rape
12.	Magdeburg	Hamburg	Rye
13.	Schwedt	Spelle	Rye
14.	Szczecin	Spelle	Barley
15.	Elbląg	Kaliningrad	Soya bruised grain

Table 2. Inland vessels used to transport agro loads based of the example of OTL Group

Specification	Type of vessel	Capacity	Number of units
Motor vessel	Motor vessel – 55 m (BM-500)	475-509 t	19
	Motor vessel –75 m	1007-1083 t	4
Push barge	Barge – 35 m (covered, lower deck)	411-482 t	55
	Push barge – 45 m (covered, cement + lower deck 500)	463-489 t	6
	Push barge – 65 m (covered, lower deck)	765-838 t	18
Total number of units			*103*

Table 3. Inland vessels used to transport agro loads based of the example of OTL Group
[Source: own elaboration based on OT LOGISTICS S.A.]

Push barge - 35 m (covered, lower deck)	
	– Capacity: 411-482 t. – Depending on the degree of stowageloading, the barge can load ca. 420 tons (moisture content, specific gravity). – Total number of units SL 35 m type in OTL Group: 55.
Push barge – 45 m (covered, lower deck)	
	– Capacity: 463-470 t. – Depending on the degree of stowageloading, the barge can load ca. 400 tons (moisture content, specific gravity). – Total number of units BP-500 type in OTL Group: 6.
Push barge (BP-800 type, lower deck)	
	– Capacity: 765-800 t. – Depending on the degree of stowageloading, the barge can load ca. 750 tons (moisture content, specific gravity). – Total number of units BP-800 type in OTL Group: 6.
Motor vessel (BM-500 type, lower deck)	
	– Capacity: 488-508 t. – Depending on the degree of stowageloading, the barge can load ca. 500 tons (moisture content, specific gravity). – Total number of units BP-800 type in OTL Group: 19.

It is necessarily that the transport units have hatch covers (stacked / slidable) in a good condition to cover the holds. The technical condition and cleanliness of the hold should be checked before each loading. The ship's hold must be properly prepared in a manner dependent on the previous load (the rules in this regard are included in the GMP + procedure). The GMP + standard was developed by the Dutch organization in 1992 as part of the "Feed for Food" program. The program was aimed to ensure a high-quality feed provided to consumers. GMP + is a combination of two GMP quality assurance schemes - Good Manufacturing Practice and HACCP - Hazard Analysis and Critical Control Points. In addition, to ensure quality management control, the GMP + system is developed in accordance with the ISO 9001 standard [7].

2. A SIMPLIFIED MODEL OF THE AGRO CARGO SUPPLY CHAIN

Taking into account the complexity and structure of transport tasks, it is important to look for optimal solutions in the field of transport. Each supply chain model includes only certain selected factors that have a limited impact on the volatility of the transport. It is not possible to build a model that would fully recreate the behavior of the object, with all possible external influences.

The article considers the optimization model of inland wheat transport to final consumers, which predicts a constant demand for cereal loads in certain time segments (average demand in a given time).

This model does not provide any rapid domestic fluctuations in demand for wheat at certain time intervals. For the analysis of the model, the transport relations presented in Figure 2 for agro cargo were used.

The problem of optimization of wheat transport was considered in accordance with the diagram in the figure, followed by the objectives, requirements and characteristics of the model.

Model assumptions:

The key points served by the wheat transport system were identified [11-13]:

1. Starting point Szczecin Elewator SNOP,
2. Entry points, i.e. N_j collection points for this cargo, j=1 ÷ n where:

    A - the load is located in Szczecin (Elewator $_{SNOP}$);

    A_1 - number of tons of wheat delivered to the Elewator $_{SNOP}$ in Szczecin;

    A_2 - the total number of tons of wheat in the Elewator SNOP in Szczecin at the moment of receiving the load.

    B - total tonnage;

    a_i - tonnage stored up in a i -warehouse Elewator SNOP;

    b_j - the demand for wheat from the j -recipient in the supply chain;

    Y_z - supplying wheat to the z-recipient outside the supply chain.

    X_i - the quantity of wheat transported from i- warehouses to customers in Bramsche and the ports of Hamburg, Magdeburg, Spelle, Vahldorf.
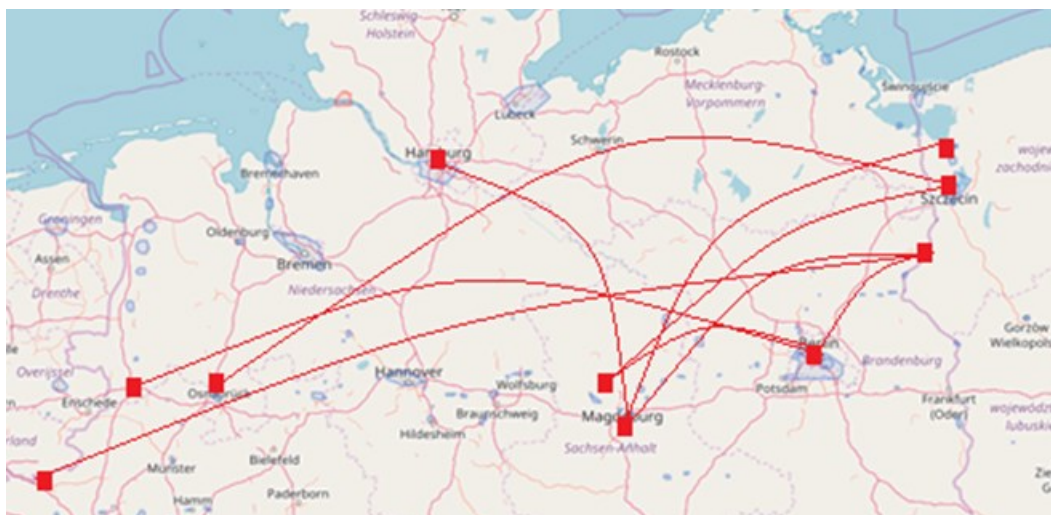

Fig. 2. Main transport connections for AGRO loads - OT LOGISTICS S.A. [Source: OT LOGISTICS S.A]

Let:

x_{ij}^k - wheat, which is transported from i – warehouses to j - recipients k - means of transport, $k = 1 \div 3$;

x_{ij}^1 - wheat, which is transported from i - warehouses Elewator SNOP to j - recipients by inland waterway transport, $j = 1 \div n$;

x_{ij}^2 - wheat, which is transported from i - warehouses Elewator SNOP to j - recipients by rail, $j = 1 \div n$;

x_{ij}^3 - wheat from port i - warehouses Elewator SNOP to j - recipients by road transport, $j = 1 \div n$;

c_{ij}^k - the cost of transporting 1 tonne of cargo from i - warehouses Elewator SNOP to j - recipients k - means of transport, $k = 1 \div 3$.

Whereby:

c_{ij}^1 - the cost of transporting 1 tonne of cargo from i - warehouses Elewator SNOP to j - recipients by inland waterway transport, $j = 1 \div n$;

c_{ij}^2 - the cost of transporting 1 ton of cargo, which is transported from port i - warehouses in Szczecinie to j - recipients by rail;

c_{ij}^3 - the cost of transporting 1 ton of cargo, which is transported from i - warehouses to j - recipients by road transport, $j = 1 \div n$.

The aim of the research is to develop a system of flexible wheat deliveries, according to the requirement of full coverage of the demand for this raw material with minimum transport costs.

Optimization criterion. The chosen measure of the quality of the delivery system is the cost of transporting the loading batch. The goal function, which is the mathematical record of the optimization criterion, is as follows:

$$f(C) = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{3} c_{ij}^k \times x_{ij}^k \to \min \qquad (1)$$

Requirements for the optimization model

A. Requiriment provision of wheat supply.

The amount of tons of wheat delivered to recipients is not greater than the amount of tons of wheat found in the Elewator SNOP, i.e.

$$0 < \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{3} x_{ij}^k \leq A_{max} \qquad (2)$$

B. Requirement to meet the demand for wheat.

The amount of tons of wheat delivered to recipients completely satisfies the demand, i.e.

$$\sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{3} x_{ij}^k = B_{max} \qquad (3)$$

Where:

$$B_{max} = \sum_{j=1}^{2} B_j + \sum_{z=1}^{3} Y_z = \sum_{j=1}^{2} b_j + \sum_{z=1}^{3} Y_z \qquad (4)$$

B_j - control variable characterizing the number of harbors on the Oder River adapted to wheat transshipment (Police, Trzebiez and Stepnica harbors);

The following definitions deserve attention:

1. Demand for wheat. It depends on the price ratio of wheat and its quantity, which consumers can and want to purchase based on the assumption that other market factors remain unchanged.

2. The volume of demand for wheat. This is the amount of wheat that buyers are willing to buy at a given time at a given price level.

3. Variability of demand for wheat. The demand for wheat changes when the factors shaping it change, including: consumer income, value in use, seasons, climate, natural disasters, etc.

C. Requirement to ensure the efficiency of transport work.

At the starting point (Port Szczecin Elevators SNOP) there are always silos with wheat to be loaded onto transport units, which gives the possibility of eliminating voyages in the direction of Port Szczecin Elevator SNOP - Bramsche:

$$x_{ij}^k > 0 \qquad (5)$$

D. Requirement of balancing demand and supply for wheat.

It guarantees consistency of restrictions (2) and (3), i.e.

$$A = \sum_{i=1}^{m} a_i = \sum_{j=1}^{n} \left(b_j + \Delta b_j\right) = B \qquad (6)$$

The second problem concerns issues related to the organization of wheat supply chains to recipients. The problem was examined in accordance with the diagram presented in Figure 3.

A description of the scheme will be entered. Let the wheat supply chain consist of three links:

- Link 1. Transport of wheat from the loading place at the wheat producer to the Port of Szczecin (SNOP Elevator), which is carried out by means of rail, inland and road transport.
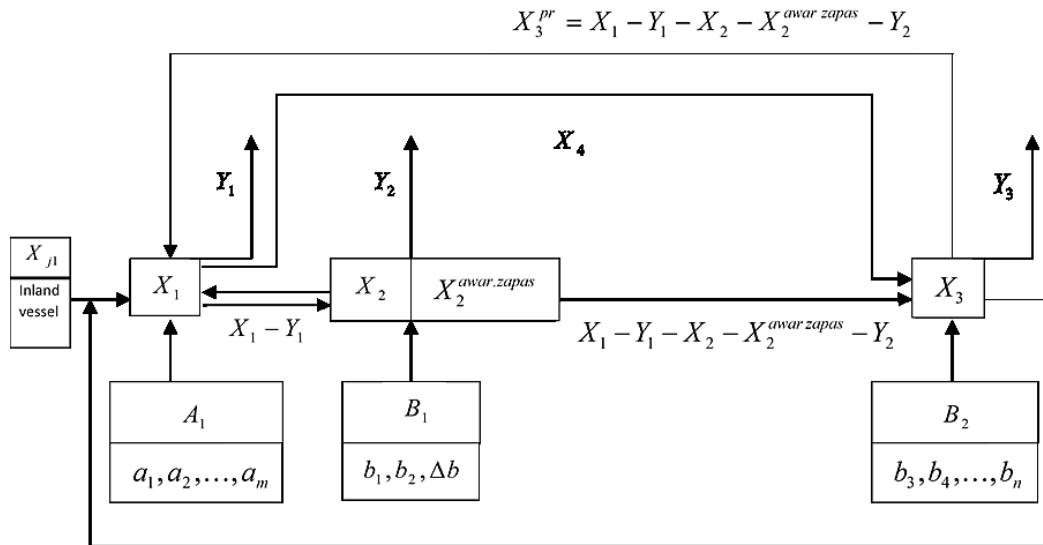
$$X_3^{pr} = X_1 - Y_1 - X_2 - X_2^{awar\;zapas} - Y_2$$

Fig. 3. The model of the wheat supply chain to final consumers. [Source: own elaboration]

- Link 2. Transport of wheat from Port Szczecin (Elewator SNOP) to Bramsche, which is made by inland transport.
- Link 3. Delivery of wheat to final consumers, which is made by means of road transport from river harbors

It is possible to transport wheat using road transport, but has it not been analyzed in the article because according to the new transport policy the share of road transport must be reduced by transferring cargo streams from roads to rail or water transport.

The need for sustainable development of transport makes inland navigation an especially attractive branch of transport. In comparison with other branches, this type of transport in the smallest range participates in external costs. The research shows that these costs per 1 tkm in inland waterway transport are 18 times lower than in road transport and 4 times lower than in railway transport [1].

The developed model is characterized by the following aspects:
I. Solutions are only sought in whole numbers.
II. The efficiency of the wheat supply chain depends on the compatibility of logistics activities performed in each of its links.
III. The time of delivery of wheat to recipients depends on weather conditions, the selected delivery means, traffic volume on the route.

IV. Each of the above supply chain links can be:
   a. characterized by input / output wheat streams;
   b. realized through the interaction of these links, because the outputs from each cell are inputs to the next links of the stream of wheat.
V. Each stream running from one cell to the next can be described by a variable, reflecting the number of wheat transported in this cell from the store to the recipients in Bramsche and in the ports of Hamburg, Magdeburg, Spelle, Vahldorf.
VI. The variable describes the number of containers that are not transported to the next link and received by the recipients, not included in the analyzed supply chain.
VII. The model assumes that there is a possibility of additional receipt of the raw material in the number of:
   a. Y1 - wheat located near Szczecin;
   b. Y2 - wheat in small Odra ports;
   c. Y3 - wheat located in the port of Szczecin.

As has shown above, under variables a_i and b_j and we will understand the number of wheat warehouses with three control variables:

$$\begin{aligned}
A_1 &= (a_1, a_2, \ldots \\
B_2 &= (b_1, b_2, \ldots \\
B_3 &= (b_3, b_4, \ldots
\end{aligned} \tag{7}$$

Where:

a_1 - The quantity of wheat collected at the Port of Szczecin (Elewator SNOP), in order to transport them to the recipients by inland transport;

a_2 - The amount of wheat collected at the railway station in Port of Szczecin, in order to transport them to the recipients by rail;

a_3 - The amount of wheat accumulated in port warehouses, in order to transport them to the recipients by road transport;

B_1 - control variable, characterizing the number of marinas on the Odra River, adapted for handling wheat (ports: Police, Trzebież and Stepnica);

$B_2 = (b_1, b_2, \Delta b)$ - characterizes the number of recipients of the supply chain.

Δb - The amount of wheat accumulated in the distribution center within the port infrastructure, e.g. silos as cargo reserve;

b_1 - The amount of wheat collected in warehouses in Szczecin;

b_2 - The amount of wheat collected in warehouses in Szczecin, e.g. Elewator Warta.

The presented transport chain can be transformed into a chain consisting of two links, provided that the first link will be directly connected with the third one, i.e. direct transport of wheat from the Port of Szczecin to final recipients. As part of the mathematical model, input and output streams of wheat in individual links of the supply chain are defined in Table 4.

Information included in the Table 4 allows to solve the problem of organization of the wheat supply chain by introducing a vector $Q_i(W_E)$ describing all input streams of loads in individual links of the supply chain, and then defining a function $f_j(Q_j)$ describing all output streams of cargo in individual supply links. Then the problem of organization of the wheat supply chain can be presented in the following way:

$$\sum_{j=1}^{3} f_j\left(Q_j\right) \rightarrow \max \qquad (8)$$

which means that the capacity of the chain should be maximum if the following restrictions are met [5]:

$$x_{ij}^{k} > 0;$$
$$\sum_{i=1}^{3} W_{E_i} = \sum_{j=1}^{J} W_{yj}; \qquad (9)$$
$$\sum W_{y_j} = \sum W_{yx_i} + \sum W_{y_y} + \sum W_{y_{aw.zap.}}$$

Table 4. Input and output cereal load streams [Source: own elaboration]

The input stream of wheat in individual links of the supply chain	The output stream of wheat in individual parts of the supply chain
First link in the wheat supply chain	
$W_{E_1} = \left\{\left(X_{1j}\right)\left(X_3^{pr}\right);\left(X_1 - Y_1\right)^{pr};A_1\right\}$	$W_{y_1} = \left\{\left(X_1 - Y_1\right);X_4;Y_1\right\}$
Second link in the wheat supply chain	
$W_{E_2} = \left\{\left(X_1 - Y_1\right);B_1\right\}$	$W_{y_2} = \left\{\left(X_1 - Y_1 - X_2 - X_2^{aw.zap.} - Y_2\right);Y_2\right\}$
Third link in the wheat supply chain	
$W_{E_3} = \left\{\left(X_1 - Y_1 - X_2 - X_2^{aw.zap.} - Y_2\right);X_4;B_2\right\}$	$W_{y_3} = \left\{X_3^{pr};Y_3\right\}$

where:

W_E - a set of input batches of containers in individual links of the supply chain;

W_y - a set of output batches of containers in individual links of the supply chain.

CONCLUSIONS

Models of agro cargo supply chains make it possible to assess the efficiency of operation of inland units and the degree of utilization of inland waterway infrastructure and river ports in handling of agricultural cargo. They will also allow to assess the degree of use of inland waterway transport in the implementation of integrated transport. Good organization of the flow of products through different segments of the chain, focuses on the linkages between different functional areas in the supply chain. The function of the supply chain is to organize the flow of cargo in such a way as to optimize the use of resources and the fastest possible transportation between the links. The supply chain can thus be

thought of as a process within which sub-processes are sought to be optimized.

It is the type of product that determines how the supply chain is built, which is why it divides products into functional and innovative. Functional products are characterized by predictable demand, long life cycles, and mostly satisfy basic needs. In contrast, innovative products have shorter life cycles and greater fluctuations in demand. The presented division of products determines the matching of the appropriate supply chain architecture for them.

For shipping to be attractive and able to compete with other modes of transport, it must be adapted to changing trends. Currently, the flexibility of a given transport branch is of great importance. More and more attention is paid to the safety and environmental performance of transport. The priority investment for Poland should be modernization to class IV waterways along the entire length of the Oder Waterway, as well as the construction of two key channels: Odra-Laba-Dunaj and the Śląski Canal. Such investments would significantly widen the circle of inland waterway customers. This would create access to the cheapest transport branch for many industrial plants.

Companies are constantly looking for ways to create competitive advantage. In the process of building this advantage, an important role is played by more frequent orientation of companies to the development of supply chains, in which logistics processes are of key importance. One type of supply chain that deserves special attention is flexible supply chains, which play an important role in the agricultural sector. It is in this sector that the rapid delivery of a product to the final customer through a flexible chain is often the most important issue.

KONCEPCJA MODELU ŁAŃCUCHA DOSTAW ŁADUNKÓW AGRO Z WYKORZYSTANIEM ŻEGLUGI ŚRÓDLĄDOWEJ

Wykonywanie zdań przewozowych wymaga uwzględnienia wielu czynników zewnętrznych i wewnętrznych zależnych od zmian zachodzących na rynku żeglugowym. Miejsce, czas i rodzaj transportowanego ładunku itp. mają wpływ na złożoność struktury systemów transportowych, przez co istotne jest badanie możliwości i tworzenie modeli optymalizacji przewozów w całym łańcuchu dostaw ładunków oraz analiza zagadnień związanych z ich organizacją, co wpływa na bezpieczeństwo i niezawodność tego typu systemów. Celem artykułu jest przedstawienie i analiza koncepcji modelu łańcucha dostaw ładunków agro, z wykorzystaniem żeglugi śródlądowej, w relacjach Polska – Niemcy na przykładzie Grupy Kapitałowej OT Logistics S.A. (GK OTL SA). Biorąc pod uwagę złożoność i strukturę zadań przewozowych istotne jest poszukiwanie optymalnych rozwiązań w zakresie funkcjonowania transportu z uwzględnieniem aspektów bezpieczeństwa i niezawodności.

Każdy model łańcucha dostaw uwzględnia tylko pewne wybrane czynniki, które mają ograniczony wpływ na zmienność przewozu. Nie jest możliwe zbudowanie modelu, który w pełni odtworzyłby zachowanie obiektu, przy wszelkich możliwych oddziaływaniach zewnętrznych. W artykule rozpatrzono model optymalizacji śródlądowych przewozów pszenicy do odbiorców końcowych, który przewiduje stały popyt na ładunki zbożowe w określonych odcinkach Model ten nie przewiduje gwałtownych wewnątrzkrajowych wahań popytu na pszenicę w określonych odcinkach czasowych.

REFERENCES

[1] Al Enezy O., van Hassel E., Sys C.H., Vanelslander T. (2017) Developing a cost calculation model for inland navigation. *Research in Transportation Business & Management*, 23, pp 64–74, https://doi.org/10.1016/j.rtbm.2017.02.006

[2] Biała księga: Europejska polityka transportowa 2010: czas na podjęcie decyzji, (2002) Wyd. Naukowe Uniwersytetu Szczecińskiego, Szczecin

[3] Beyer, A. (2018) Inland Waterways, Transport Corridors and Urban Waterfronts. *International Transport*, Forum Discussion Papers, OECD Publishing: Paris, France

[4] Caris A., Limbourg S., Macharis C., van Lier T., Cools M. (2014) Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges, *Journal of Transport Geography*, 41, pp 126-136, https://doi.org/10.1016/j.jtrangeo.2014.08.022

[5] Durajczyk P. (2020) The Analysis of the Possibility to Improve the Efficiency of Container Transport Via the Oder Waterway with the Use of the RIS System. *Naše more: znanstveni časopis za more i pomorstvo*, 67(3), pp 199–208, https://doi.org/10.17818/NM/2020/3.3

[6] Galor W. (2017) Sea-river shipping in Polish inland waters. *Scientific Journals of the Maritime University of Szczecin*, 50(122), pp 84-90, https://doi.org/10.17402/220

[7] GMP+ B4.2 - Fracht morski i śródlądowy

[8] Kotowska I., Mańkowska M., Pluciński M. (2018) Inland Shipping to Serve the Hinterland: The Challenge for Seaport Authorities. *Sustainability* 10(10), 3468, pp 2-17, https://doi.org/10.3390/su10103468

[9] Kozerska M. (2013) Inland waterway transport in Poland – the current state and prospects for development. *Scientific Journals of the Maritime University of Szczecin*, 47(119), pp 136-140, https://doi.org/10.17402/160

[10] Kulczyk J, Winter J. (2013) *Śródlądowy Transport Wodny*, Oficyna Wyd. Politechniki Wrocławskiej, Wroclaw, Poland, ISBN 978-37-0857-200-0

[11] Mańkowska M. (2019) The competitiveness of cross-border transportation networks: a case study of the Szczecin–Berlin inland waterway. *Scientific Journals of the Maritime University of Szczecin*, 58(130), pp 93-104, https://doi.org/10.17402/341

[12] Restel F., Skupień E. (2011) „Analiza niezawodności transportu łamanego na przykładzie korytarza transportowego Odrzańskiej Drogi Wodnej", *Logistyka*, 6/2011, pp 3543-3552

[13] Škerlič S. (2018) The impact of customers' demands for lower logistics costs in the automotive industry supply chain on companies' business processes. *Scientific Journals of the Maritime University of Szczecin*, 55(127), pp 86-92, https://doi.org/10.17402/305

[14] Wiegmans B., Konings R. (2015) Intermodal Inland Waterway Transport: Modelling Conditions Influencing Its Cost Competitiveness. *The Asian Journal of Shipping and Logistics*, 31(2), pp 273-294, https://doi.org/10.1016/j.ajsl.2015.06.006

[15] Wiegmans B., Witte P., Spit T. (2015) Characteristics of European inland ports: A statistical analysis of inland waterway port development in Dutch municipalities. *Transportation Research Part A: Policy and Practice*, 78, pp 566-577, https://doi.org/10.1016/j.tra.2015.07.004

[16] Caris A., Limbourg S., Macharis C., van Lier T., Cools M. (2014) Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges. *Journal of Transport Geography*, 41, pp 126-136, https://doi.org/10.1016/j.jtrangeo.2014.08.022