TransNav
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 19
Number 1
March 2025
DOI: 10.12716/1001.19.01.21

Innovative and Sustainable Approaches to Urban Waterborne Transport: Insights from Gdynia Port City

A. Wawrzyńska, A. Przybylowski & M. Baziuk
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: In order to face current challenges, cities need to introduce and enhance resilient, sustainable and innovative decarbonisation policies and strategies. This also includes coastal urban areas, suffering from particularly heavy congestion, where local and regional authorities and other stakeholders should promote novel environmental-friendly, socially accepted and economically effective mobility patterns. Thus, the paper presents urban waterborne transport development prerequisites and conditions taking as a case study Gdynia located at the Baltic Sea in Poland. Its aim is to explore the tailor-made possibilities and solutions to create a ferry connection recommended in order to enhance sustainable and innovative mobility in the analysed city port area. The study focused on the selected variants investigating possibilities for allowing vessels with alternative fuels, appropriate length and draft parameters to approach existing locations. The paper is based on scientific papers, available industry reports, feasibility studies, urban policies and cities current experiences in planning and operating water transport. Urban waterborne transport development requires an interdisciplinary and multilevel perspective and approach so that future urban strategies contain a complex set of goals and actions to be successfully implemented by decision makers.

1 INTRODUCTION

We are becoming increasingly aware of our impacts on nature and therefore more emphasis is being concentrated on sustainable solutions. The reason for this is not only a sense of responsibility for the natural environment, but also improving the quality of life in a broad sense. Also, appropriate actions are being taken in the field of transport and mobility. More ecological, less burdensome and more favourable conditions for travellers are being sought. The factors determining the commuting choice are mainly travel time and cost. Less attention is paid to comfort. At the same time, growing awareness in society means that the impact of the chosen means of transport on the environment is becoming an increasingly important decision-making factor [1]–[5].

Inland waterways transport, including ferry connections, are very popular in agglomerations through which various types of water canals run. Ferries create an indispensable complementary network to land means of public transport [4]–[9]. Using ferry connections provides passengers with the opportunity to shorten the distance to be covered. Another positive aspect is that city authorities gain a tool with which they can encourage residents to choose public means of transport for everyday travel. The use of a small passenger-bicycle ferry will encourage new users to at least partially give up traveling by car.

Gdynia is a port city located in the northern part of Poland [6], [10]. The city area is divided by a port canal that penetrates into the land, which clearly affects the transport routes connecting the northern part with the rest of the area. The specific situation of Gdynia causes congestion on the roads and the creation of critical points that affect means of transport. Implementing a city ferry crossing at the very beginning of the port canal would allow for the creation of an alternative route leading to the northern districts. The paper presents urban water transport development prerequisites and conditions taking as a case study Gdynia located at the Baltic Sea in Poland. Its aim is to explore the tailor-made possibilities and solutions to create a ferry connection recommended in order to enhance sustainable and innovative mobility in the analysed city port area. The study focused on the selected variants investigating possibilities for allowing vessels with alternative fuels, appropriate length and draft parameters to approach existing locations. Based on the analysis carried out, three variants of the creation of the crossing were proposed in the work.

2 WATERBORNE TRANSPORT DEVELOPMENT TENDENCIES WITH A SPECIAL EMPHASIS ON THE FERRY CONNECTIONS

While according to Eurostat inland waterways transport represents only 6% of the modal split in the EU, it presents better results regarding accidents, air and noise pollution, effects on climate, and congestion. At the same time, in some countries as The Netherlands, where the inland waterways network is developed, its share reaches 40%. The EU has recognised the importance of a modal shift from road hauling to railways and inland waterways transport. With the European Green Deal [11], the European Commission aims to shift part of the current roadhauled goods to more sustainable inland transport [12].

The construction of transportation infrastructure is based on two fundamental factors shaping and limiting its development: the demand for the movement of people or cargo, and the terrain, which is in the line of the selected location routes. Demand for movement, shapes the search for connections between points, in turn, the relief and type of terrain affect the connections that are formed [13]–[16].

The same factors also influence the development of waterborne transport, including ferry connections. According to the definition, a ferry crossing is a way of moving people, cars, trains and cargo by ferry, between fixed points of loading and unloading. Ferry crossing, depending on the type of body of water, can be carried out using sea ferries, inland ferries or smaller vessels [17]. A ferry is a water vessel used to transport people and cargo across canals, seas, reservoirs or rivers. The ferry is usually moved by self-propulsion or is pulled by means of a hanging rope [18]–[22].

In the context of the analysis of the city's transportation network, the greatest demand for ferry service will arise in agglomerations located at the sea, in the estuary and along the natural course of rivers, or in the area of the extensive canal network. It is uneconomic to create freight connections within the city. Ferry solutions are mainly designed to facilitate the movement of pedestrians, cyclists and public transport passengers within the city. Often introduced ferry solutions in cities become a curiosity for tourists to enjoy [23]–[27] .

The project to create a ferry service (urban or marine/interland) will always raise many questions and doubts, due to the huge financial outlay needed to make the crossing operational. A properly operating crossing needs a minimum of two terminals, a vessel and an entity responsible for maintaining the line. These are huge costs that must be incurred for the new link to take off. Only then can it be verified in practice whether the studies and predictions were accurate. Adequate research that most likely replicates the demand for the crossing requires the assumption of basic scopes that must be examined:

- economic efficiency (profitability),
- crossing time,
- number of ports and terminals,
- route load/demand,
- investment costs [25]–[28].

Vessels operating on urban ferry services are generally small in size, about 22-24 meters, and the routes on which they operate are a few hundred meters at most. The short distance, the relatively small number of passengers and the convenient water conditions have a positive effect on the level of safety requirements, the fulfilment of which does not pose additional problems, providing a cost-optimal vessel that, thanks to the open space and freedom of movement on board, will provide a comfortable journey for passengers. With the assumption of serving only pedestrian and bicycle passengers, favorable conditions will be created for the use of modern electric or hybrid units [32]–[35]. These two types of units have gained a great deal of popularity in recent years thanks to the extraordinary development of batteries and rechargeable batteries. Fast charging stations at the shore, efficient and capacious batteries ensure the possibility of a trouble-free, environmentally friendly application of these types of units on urban ferry routes. Societal pressure, which exerts great influence to use electric ferries as often as possible, plays a huge role in planning connections. In cases where there is a high intensity of operation that makes it difficult to recharge batteries or there are financial barriers, hybrid-powered units are being used in ferry service [36]–[42].

There are some logistics advantages of passenger inland ferries. In Norwegian Bergen it concerns remote parking terminals, saving significant travel distance and cut the cost of crew facilities in terminals [43]. These solutions are also a promising future in Russia [44] and in Germany [[46]. Some researchers combine autonomous transport with zero-emission ferries as a better option for sustainable urban mobility [25]. There are numerous benefits of sustainable ferries for urban mobility: increasing public transport network connectivity, reduced travel distance, and fostering modal shifts towards foot travel and bike riding [23].

However, some important questions arise from a legal perspective in view of a complete operational implementation of autonomous inland waterways transport. The allocation of liability, including extracontractual one, is an important concern for shipowners wanting to invest in autonomous vessels, and for other stakeholders. That is why, a balanced risk distribution framework could boost the investment decision [45][42]-[47].

Also, the autonomous vessel elaborated by MIT scientists Roboat II (fig. 2) is designed to carry passengers for urban mobility [47], [48].

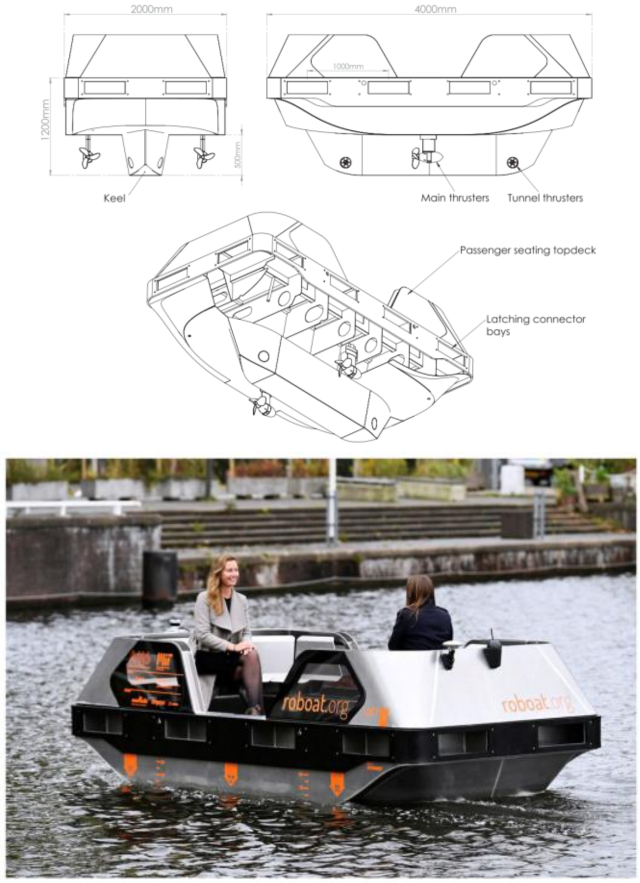

Figure 1 Mechanical design of the Roboat prototype [49].

In Paris, for example, four 15-meter-long 100% electric boats, worth 1.3 million each, sail at a speed of 20 km/h and can accommodate many passengers. This operation has been carried out in the framework of the organization of the Olympic Games in Paris in 2024. These shuttles operate completely autonomously. A captain and sailors are to be present on board just to ensure that everything goes smoothly.

The tab. 1 presents a summary of selected examples of electrification of ferry vessels. Several of them are also autonomous units and it can be expected that the number of autonomous ferry connections will only increase. In Europe, Norway is leading the way, being very consistent in the electrification of ferry connections in particular, and at the same time having a number of projects underway to introduce autonomous units [49].

Table 1 Characteristics of selected examples of electrification and/or autonomous ferry vessels

Operating area	Characteristics of the crossing	Characteristics of the vessel
Lorient i Pen-Mané (France)	frequency: 28 sailings per day	length: 22 m,passenger seats: 113; cargo capacity: 10 bicycles, 3 wheelchairs propulsion: supercapacitors; running time: 7 min; loading time: 4 min
Paris Seine (France)	Seine river	length: 22 m; operation was carried out in the framework of the organization of the Olympic Games in Paris in 2024; 4 ex. autonomous electric ferry, autonomous mooring
Stockholm: Movitz Ferry Sweden)	cruises in the summer season	after deep modernization; length: 23 m; passenger seats: 100; speed: 16 km/h el. drive: 2x125 kW, battery capacity: 180 kWh operating time: 1 h; charging time: 10 min
Stockholm: Sjovagen Ferry (Sweden)	frequency: 8 sailings per day (10 stops); cruise time: 50 min	passenger seats: 150; cargo capacity: 15 bicycles, 6 wheelchairs and 8 baby carriages el. drive: 2x160 kW; battery capacity: 500 kWh; charging at night and 2 times during the day
Stockholm (Kungsholmen - Soedermalm)	several minutes	length: 12 m; passenger seats: 30 autonomous electric ferry, propulsion system driven by electricity supplied via onboard solar panels
Amsterdam (Netherlands)	cruise time: 5 min	length: 34 m; passenger seats: 310; cargo capacity: bicycles and mopeds Diesel propulsion: 4x133 kW; el. drive: 2x250 kW; battery capacity: 2x68 kWh
Kaohsiung (Taiwan)	distance: 650 m frequency every 15 minutes	refurbished; length: 23 m Diesel propulsion: 2x225 kW; electric drive: 130 kW (direct current);battery capacity: 100 kWh
London: Woolwich -North Woolwich (United Kingdom)	cruise time: 5 min	2 ex.; length: 62 m; passenger seats: 150; cargo capacity: 45 passenger cars hybrid propulsion; battery capacity: 181 kWh
Trondheim (Norway)	distance: 100 m	length: 8-10 m; loading capacity: 12 persons, bicycles and wheelchairs electric propulsion: 4x4 kW autonomous ferry under construction
Fredrikstad (Norway)		Medium ferry (50 PAX) New electric ferry delivered in June 2019. Evaluating future autonomous operation.
Oslo (Norway)		A large number of medium-sized passenger ferries are in use already
Copenhagen (Denmark)	Daily working hours: 16 h	5 Damen Ferry 2306 E3 vessels; length: 23 m; Passenger seats: 80; cargo capacity: 8 bicycles Electric drive: 2x55 kW; battery capacity: 120 kWh; loading at end stops: 7 min each
Kiel (Germany)		length: 31.57 m; passenger seats: 30; (Source:) Hybrid ferry, battery capacity: 340 kWh;

Source: own elaboration based on: [49-57] and other available data.

3 GDYNIA PORT CITY TRANSPORT NETWORK SUSTAINABILITY CHALLENGES

Gdynia is a city located in Poland and is one of three cities in the Tricity agglomeration. In 2022, Gdynia had a population of 242 000, and the city's area was 135 square kilometers. The location of the city, not coincidentally, was chosen about 100 years ago because of the need to build a port and shipyard on the Bay of Gdansk. The harbor channel, visible in Figure 1, cuts deeply into the land, separating the city into two parts. Currently, there is no bridge over the port channel and no ferry crossing. The only way to get from one side of the canal to the other is to drive around. In Gdynia in 2022, the ratio of passenger vehicles per 1,000 residents was almost 700. This is a very high number that directly affects urban transport system sustainability resulting in road congestion, air quality and travel time [58].

The analysis requires taking into account the structure of two districts: the Oksywie and Śródmieście. Oksywie is located north of the harbor channel. The area of the district is 4.37 square kilometers and the area has a population of 14 376. It is a district with mainly residential buildings in the area.

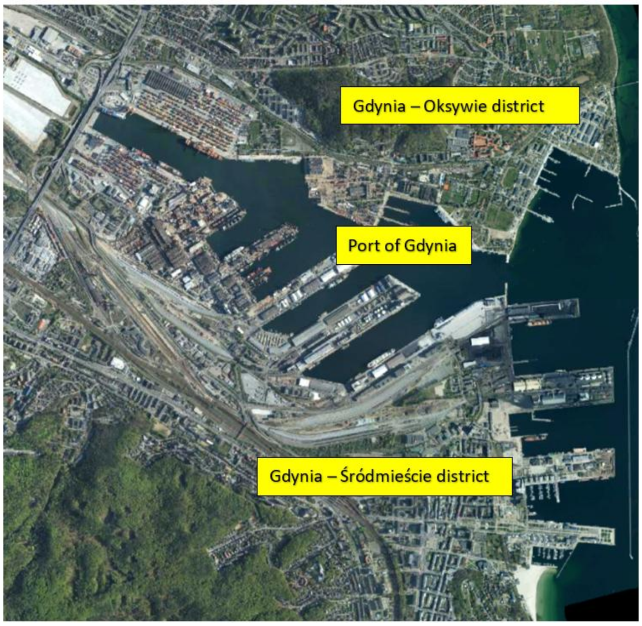

Figure 2 Situation plan of the analyzed connection between the districts of Gdynia: Oksywie and Śródmieście Source: Own based on Obliview Gdynia

The district is home to infrastructure of strategic importance to the state, the land along the port channel belongs to the Navy. In the military areas there is a naval port, a naval shipyard and the Naval Academy. There are also points of tourist and recreational importance in this district: the seaside promenade and the beach.

The Śródmieście district, on the other hand, is located in the central part of the city and south of the harbor channel. The district has a population of 11,556 and an area of 11.49 square kilometers. The district's areas are characterized by a wide range of uses, including residential areas, service and office development, and industrial and shipyard areas. It is within this district that the harbor channel is located. Śródmieście is home to infrastructure elements important to residents traveling to other areas of the city, province and country. There is a train station, a commuter rail station and a bus station.

It is worth mentioning about the plans to introduce passenger traffic on the rail line running through the Oksywie district. After adjusting the line to handle agglomeration traffic, the route from Oksywie would connect with the current SKM train line at the level of the Gdynia Chylonia stop. Such a connection is a solution whose implementation is needed and beneficial. However, the creation of a rail connection does not interfere with the ferry crossing project under construction, due to the fact that the line reaches the city center in a rather wide arc, and for some travelers a direct ferry to Downtown will be a more attractive means of transportation. The ferry service could even interact with the rail line. Travelers from nearby neighborhoods along the line, could be bused to the ferry. Likewise, travelers from the ferry would have the option of transferring to a train for onward travel. The train stop is a short distance from the ferry's conceptual solutions.

The idea for the creation of the Gdynia Śródmieście - Gdynia Oksywie ferry crossing is intended as a starting point for further analysis, the end goal of which would be to create an alternative way for residents of Oksywie and neighboring districts in the municipalities to travel on this route. The problems described earlier, resulting from the harbor canal entering Gdynia, mean that the resulting solution could become an alternative to road connections and influence an increase in the share of sustainable modes of transportation in urban travel. A direct, short connection could encourage residents to continue their journey using public transportation, bicycles or to cover part of the trip on foot. This section proposes several variants of routes and locations in which a ferry crossing could operate for residents between Gdynia Śródmieście and Gdynia Oksywie.

Touching on the previously mentioned elements that need to be defined when creating a plan, they start with economic efficiency. The crossing will certainly have to be maintained as part of the city's public transportation network. Operating costs will significantly affect the city's budget. A solution should be sought that will affect the authority's finances as little as possible. The vessel should be lightweight, small and have low electricity consumption. Due to the short distances to be traveled, the ferry will be able to be electrically powered and recharged while stationary at terminals. The passenger vessel should take on board passengers on foot, cyclists, baby carriages, cargo bicycles and wheelchair users. A positive aspect that would encourage additional passengers would be the possibility of bringing scooters and mopeds on board the ferry. Due to the prevailing weather conditions, to ensure the comfort of the trip, there should be an enclosed section on the vessel where passengers can stay during crossings in winter, rains or during strong winds.

Another aspect is the crossing time, which should be as short as possible to attract potential passengers as much as possible. It should be a crossing that allows quick movement, not a tourist ferry to view the port from the water. Depending on the location of the terminals, the crossing time will be affected more or less by the traffic of other vessels in the port. It is to be expected that larger vessels will take precedence over a small passenger ferry. A ferry on this route should exhibit high maneuverability and dynamic movement in order to take advantage of the windows that appear between other, larger vessels. Necessary to indicate is the number of ports and terminals. The route will include two terminals where the vessel will have its stops. One of the harbors should be designed to ensure that the vessel can safely stop at night. Defining the demand and load of the connection is another important element of the concept. Assuming that the chosen route will be attractive from the point of view of a potential passenger, one should expect increased demand for travel during the morning and afternoon hours from Monday to Friday. During weekday evenings and weekends, those using the crossing will be tourists and locals who go to the center to spend their leisure time. On weekends, especially those with favorable weather conditions, traffic may be increased, but spread evenly throughout the day. Increased marketing efforts should be made to promote among residents the use of the crossing for more than just recreational purposes. It is advisable to create a program to encourage travelers to make regular trips.

An important factor that defines the emergence of investment is investment costs. The scale of the project and the momentum make it virtually impossible to finance the investment with municipal funds alone. The cost of purchasing a vessel, adapting and building terminals and operating facilities will run into the millions. Funding for the investment should be sought from the central budget or external subsidies, such as EU funds for the development of sustainable transport in cities. Investment with private funds is practically impossible due to the subsequent lack of return on investment. The northern part of Gdynia is a lot of undeveloped areas that will develop rapidly in the near future, especially the residential part. The already existing barriers and bottlenecks in the transportation system exert a strong pressure to create alternative connections, such as a ferry service or the launch of light rail. Both solutions can work together to provide a loop in the public transportation network.

4 CONCEPT OF A NOVEL FERRY CONNECTION IN GDYNIA CITY PORT

In this section, 6 variants with varying degrees of reference to the existing condition at the location have been presented. When designing a ferry crossing in a city, it is important to keep in mind the previously mentioned factors that will significantly affect the variants: economic efficiency, crossing time, number of ports/terminals, route loading and investment costs. Due to the complexity of the process and the lack of detailed data on, for example, the cost of building a ship, some elements of the concept will be addressed to a lesser extent. A key element affecting the concepts to varying degrees will be the exclusionary areas established by the Minister of Defense. The excluded area includes the Naval Academy, the Naval Port Gdynia and part of the port basins located at wharves used by the Navy. On each of the variants, the scope has been placed in green closed terytory of Naval Port. In addition, the projected construction of the Outer Harbor is an extremely important element. In the case of two variants (I and III), the expansion of the port here will be crucial to extending the route of the projected ferry line.

An introduction is necessary before starting the analysis of options. The starting and ending points are marked in a special way:

- Point A1, is a point on the Pomorskie quay, in the absolute heart of Downtown (also called Śródmieście), most convenient for passengers on foot,
- Point A2, is an intermediate point between the BCT terminal and the Navy Port (which is a restricted zone). Performing passenger access in this mijecu would be a very convenient option for direct access to the Śmidowicza street for residents of the Oksywie district without the need for another means of transportation,
- Point A3, is a point at the end of the Helskie Quay in the direct location of the Kwiatkowski Estacade, from here travelers would be able to transfer to go further towards the northern districts of Gdynia, including Obłuże and Pogórze,
- Point B1, is a point in the vicinity of the Marine Station in Gdynia, at the Fińskie Quay in the immediate vicinity of the Ferry Terminal (therefore having the necessary hydro-technical infrastructure), however, it is a place somewhat distant from the strict center of Downtown and requiring the choice of another means of transport to get here from the center of Gdynia,
- Point B2, is a point at the site of the Babie Doły ferry terminal, which does not currently exist, but is essential for the various variants of the proposed routes.

Means of transportation included in the analysis are as follows:

- inland passenger ferry; example units with technical dimensions and possible number of passengers to be transported, units powered by electricity or hydrogen fuel, andt about the ptencial possibilities of using autonomous units;
- inland passenger-car ferry; examples of units, along with technical dimensions and the number of passengers and cars that can be carried.

Table 2 presents the most important information on the details of the proposed routes and the type of units serving each alternative. Hence, the following description of each alternative focuses only on the functional and spatial analysis of each alternative.

Variant I, is the concept that appears to be the most attractive from the point of view of a passenger traveling exclusively by public transportation (Fig. 3). The route begins at Pomorskie Quay, in the center of Downtown Gdynia, while it ends at Helskie Quay in the vicinity of the Kwiatkowski route, and would be an excellent transfer point for passengers heading toward Oksywie or the neighboring districts of northern Gdynia. At the same time, an intermediate stop is planned along the route. Serving passengers from the Oksywie districts, allowing faster passage in the direction of the Oksywie district center. This connection effectively avoids traffic jams and saves time at the level of about 30 minutes. The essential element of this variant is the possibility of direct transport from the center of Downtown to the Oksywie district analyzed in the work. At the same time, it is a variant in which transport is carried out by a small vessel designed exclusively for the transportation of passengers and, what is extremely important, it is a variant that does not take into account the planned expansion of the Port of Gdynia by the External Port, which will soon take place. So where did the idea to introduce such a variant come from? Especially since one must be aware that after a short time this variant will not be possible to implement? Well, according to the Authors, it would be an excellent opportunity to promote this mode of transport and get people used to the fact that sea transport in a port city is an ordinary way of covering a certain distance, which can be used interchangeably with land transport. After the construction of the Outer Harbor, maintaining this connection would lose its sense due to significantly increasing distances, and would naturally have to be replaced with the route presented in options: IV, V and VI. In these variants, the beginning of the route is planned in the vicinity of the Marine Station in Gdynia and by the ferry crossing currently in use.

Figure 3. Variant I - passenger ferry from Pomorskie Quay towards Kwiatkowski Estacada, a variant that does not take into account the planned expansion of the Port of Gdynia by the Outer Port Source own work based on SIPAM

Variant II, is a proposed passenger-car train service, along the lines of the crossings operating for many years in Swinoujscie, details of which the Reader can find, for example, in [A]. The beginning of the crossing, is the terminal at the Marine Station, and the end stop the authors proposed in the Babie Doły location. In this case, a ferry stop would have to be designed at this location. Such a passenger-car crossing would significantly relieve traffic along Kwiatkowskiego Estakada, but would require significant financial outlays necessary to build hydro-technical infrastructure for the designed ferry terminal and to prepare a waterway to the terminal providing adequate depths for a passenger-car ferry. Variant II is independent of the construction of the External Port and can be implemented at any time.

Variant III is a combination of the above two variants and can be implemented under the same conditions as the above two variants. So where did the idea for such a solution come from? It would be a comprehensive solution, enabling a complete improvement of transport accessibility to the northern districts of Gdynia. It would be an opportunity to change the habits of passengers and indicate the possibility of choosing the best transport connection from the two proposed in this variant.

Figure 4. Variant II - passenger-car ferry from the Fińskie Quay in the vicinity of the Marine Station, towards Babie Doły Marina, non-dependent variant of the planned expansion of the Port of Gdynia with the External Port Source own work based on SIPAM

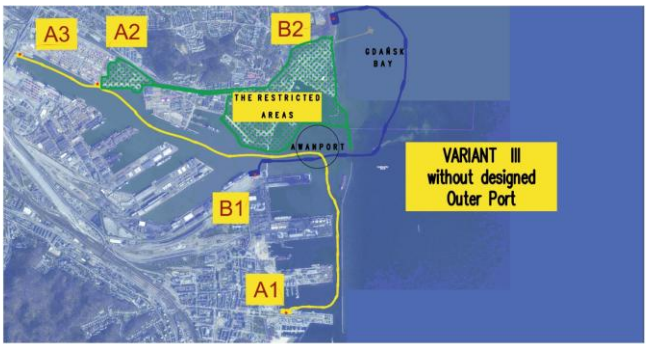

Figure 5. Variant III - a variant combining the above two variants, taking into account both the passenger ferry from Pomorskie Quay in the direction of Kwiatkowski Estacada and the passenger-car ferry from the Finnish Wharf in the vicinity of the Marine Station, in the direction of Babie Doły Marina, a variant that does not take into account the planned expansion of the Port of Gdynia by the Outer Port Source own work based on SIPAM

Variant IV, is the option that assumes the existence of the External Port. The construction of the Outer Port in Gdynia naturally removes Variant I from the option. Instead, a solution is proposed in which the beginning of the passenger crossing will be in the vicinity of the Marine Station in Gdynia. At the same time, the introduction of two routes is assumed, but only as a passenger connection. Thus, it is assumed that the first route has a beginning in the vicinity of the Marine Station in Gdynia, and then runs along the Helskie quay until the end of the Port Canal in the vicinity of Kwiatkowski Estacada, and the second route, which also has a beginning in the vicinity of the Marine Station, but would lead to Babie Doły marina, the assumptions of which are presented in the description of Variants II and III. The authors assume that launching a new means of transportation on only one route and to a rather limited extent, is not a sufficiently adequate motivation to change the route choice habits of Gdynia residents. Therefore, if a decision were to be made to introduce a new means of public transport, it is worth considering the proposal of route choice by a potential passenger. It is worth mentioning at this point that, unlike a car-passenger crossing, a passenger-only ferry requires less depth both on the approach track and in the harbor itself.

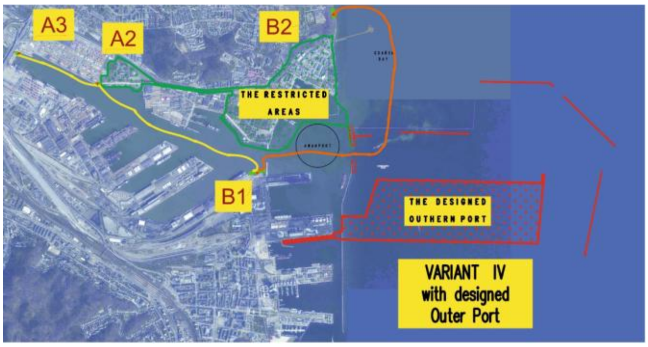

Figure 6. Variant IV - two independent routes of passenger ferry connections are proposed, both having their beginning at the Fińskie Quay in the vicinity of the Marine Station,the first route in the direction of Kwiatkowski Estakada, and the road in the direction of Babie Doły Marina, the variant taking into account the planned expansion of the Port of Gdynia with the External Port Source own work based on SIPAM

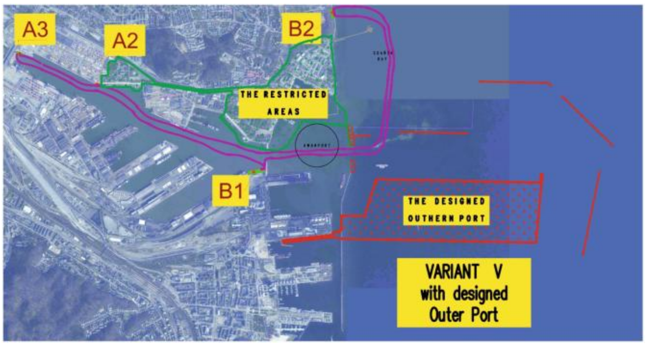

Figure 7. Variant V - one extended route served by a passenger ferry is proposed, starting at the Finnish Quay in the vicinity of the Marine Station, and then leading through the Port Channel to the route towards the Kwiatkowski Estacada, and the road towards the Babie Doły Marina, a variant taking into account the planned expansion of the Port of Gdynia with the External Port Source own work based on SIPAM

Variant V, shown in Figure 7, on the other hand, is a combination of the two above-mentioned routes into a single, albeit significantly longer, route. At the same time, only a passenger crossing is designed here. The proposed variant basically assumes only the beginning of the route (in the vicinity of the Marine Station) and making a loop along the port channel and Babie Doły marina. Why would such a variant serve? It is mainly about the distribution of passenger stops and minimizing the required vessels. At any one time, one vessel would be enough to serve the route instead of the necessary two in the previous variant.

The last of the proposed solutions, Variant VI, is also a variation on the previous ones. Firstly, it assumes the existence of the External Port, hence the beginning of the route in the vicinity of the Marine Station, secondly two types of ferries: passenger and car ferries, and thirdly it assumes the construction of a marina in Gdynia Babie Boły. With a proper promotional campaign, especially with the introduction of a ferry connection from Downtown Gdynia, such a variant could prove to be a very good solution, permanently changing the lives of Gdynia's residents.

Table 2, Specification of analyzed variants with respect to route length, number of stops, type of unit

Conditions	Variants					
	Variant I Fig. 3	Variant II Fig. 4	Variant III Fig. 5	Variant IV Fig. 6	Variant V Fig. 7	Variant VI Fig. 8
Consideration of the construction of the Outer Port	NO			YES		
Route	A1 Kosciuszko Square (Helskie quay)/ A2 Boundary of the MW Port and BCT Terminal (Helskie quay/ A3 Helskie quay at Kwiatkowski estacada	B1 Maritime Station (Fińskie Quay)/. B2 Babie Doły Marina	A1 Kosciuszko Square (Helskie quay)/ A2 Boundary of the MW Port and BCT Terminal (Helskie quay/ A3 Helskie quay at Kwiatkowski estacada	B1 Maritime Station (Finskie quay)/ A2 Boundary of the MW Port and BCT Terminal (Helskie quay)/ A3 Helskie quay at Kwiatkowski estacada	B1 Maritime Station (Finskie quay)/ A2 Boundary of the MW Port and BCT Terminal (Helskie quay)/ A3 Helskie quay at Kwiatkowski estacada B2 Babie Doły Marina	B1 Maritime Station (Finskie quay)/ A2 Boundary of the MW Port and BCT Terminal (Helskie quay)/ A3 Helskie quay at Kwiatkowski estacada
			B1 Maritime Station (Fińskie Quay)/. B2 Babie Doły Marina	B1 Maritime Station (Fińskie Quay)/. B2 Babie Doły Marina		B1 Maritime Station (Fińskie Quay)/. B2 Babie Doły Marina
Distance approx.	6,5 km	4,5 km	1. 6,5 km 2. 4,5 km	3.8 km 4.5 km	13,4 km	3.8 km 4.5 km
Number of stops	3	2	3/2	2/2	4	3/2
Passenger Ferry/Water Tram	YES	NO	YES	YES	YES	YES
Passenger-vehicle ferry	NO	YES	NO	YES	NO	YES
Number of vessels	1	1	2	2	1	2
frequency of crossing / per day	24	12	24 12	24 18	36	24 12
Number of pasengers	100	400	100 400	100 100	100	100 400
Number of cars	0	0	60	0	0	60

Source: own elaboration

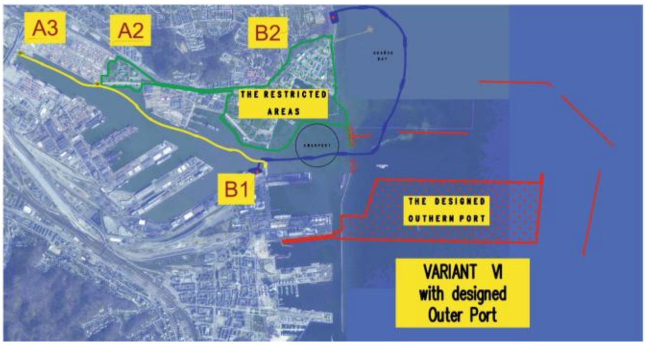

Figure 8. Variant VI – taking into account both the passenger ferry from the Fińskie Quay towards Kwiatkowski Estacada and the passenger-car ferry from the Quay, towards Babie Doły Marina, a variant taking into account the planned expansion of the Port of Gdynia with the Outer Port Source own work based on SIPAM

The limitation of this analysis is a lack of a decent identification of funding sources and the definition of a management model. Also, future research should concentrate on the need to use the CBA method as necessary to assess the economic efficiency of implementing such a project.

5 CONCLUSIONS

The intention of the Authors was to indicate the possibility of using a floating ship as a means of transportation that could improve transport links between the northern districts of Gdynia, including primarily the Obłuże district. Variants I and III do not include the construction of the Outer Port in their assumption. In this situation, they could be applied in the short term. The construction of the Outer Port would force a longer route, which in effect, both in terms of economics and increased crossing time, would make the crossing unprofitable. However, it has been included in the considerations, since the construction of the Outer Port has not yet begun, and from the point of view of the attractiveness of the project, it is the stopping of autonomous units and the transport of passengers by these units from the Pomorskie quay, in principle from the center of Śródmieście, that would be the most convenient solution. Variant II and Variants IV and VI include a passenger-car crossing, which in essence does not change whether it remains the only proposal or is an additional option to accompany the passenger crossing.

At present, the most likely solutions to be implemented are Variants IV-VI. Variant IV proposes two independent routes: the first in the direction of Kwiatkowski estacada with a stop at the border of the Navy Port and BCT Terminal, and the second in the direction of Babie Doły Marina. Of course, both would have their beginning in the vicinity of the Maritime Station , it is proposed to start at the site of the Finkie Quay. The hydrotechnical infrastructure is ready there, and adequate depths at the wharf are also provided. Analyzing the aspect of hydrotechnical infrastructure, both A1 (Maritime Station or Kosciuszko Square), as well as A2 (Helskie quay at the border of BCT and MW) and A3 (Helskie quay at Kwiatkowski estacada), have ready and adequate technical infrastructure, as well as depths at the quay. In contrast, the situation is different for the Babie Doły marina. Here it would be necessary to build a berth for both a passenger-car vessel and a passenger vessel. Moreover, given the existing depths, it would also be necessary to carry out dredging work on the leachate leading to the marina.

Already in 2021 the Vice-mayor for economic affairs (and current Vice-President for Finance and Asset Management of Port of Gdynia Authority) revealed that city of Gdynia was thinking not only about hydrogen public transport solutions, but also about a water tram running between the districts and decongesting the city port area in this way. However, there are some concerns about the feasibility of implementing them: technical, techonological, managerial and also financial ones. Also, the local authorities and higher education institutions show the involvement in this respect. Subsequently, at Gdynia Maritime University (GMU) premises a meeting with participation of public transport representatives, LOTOS petrochemical company and other key stakeholders was organised to discuss possibilities to launch such a hydrogen ferry connection and eventually an autonomous one in future. Finally, more research is required to evaluate the full picture and to propose solutions allowing seamless implementation of waterborne transport connections, including low-emissions and autonomous ones [59], in the modern seaport agglomerations.

REFERENCES

[1] T. Abramowicz-Gerigk, Z. Burciu, M. K. Gerigk, and J. Jachowski, “Monitoring of Ship Operations in Seaport Areas in the Sustainable Development of Ocean–Land Connections,” Sustain., vol. 16, no. 2, 2024, doi: 10.3390/su16020597.
[2] A. Cuculić, I. Panić, J. Ćelić, and A. Škrobonja, “Implementation of Charging Stations for Hybrid and Electrical Ferries in Croatian Ports,” J. Marit. Transp. Sci., vol. Special edition 4, no. 4, 2022, doi: 10.18048/2022.04.10.
[3] L. Aboud, O. M. Massoud, and A. A. Tawfik, “Zero Emissions Ferries Utilizing PV/ Shore Connection Hybrid Power System,” 2021.
[4] L. M. Aboud and O. M. Farid, “Eco-friendly Suez Canal Ferries Incorporating PV/Shore Connection Hybrid Power System,” Nav. Eng. J., no. 134, 2022.
[5] A. Berntsen, S. Sæther, J. Røyrvik, M. E. Biresselioglu, and M. H. Demir, “The Significance of Enabling Human Consideration in Policymaking: How to Get the E-Ferry That You Want,” Front. Psychol., vol. 12, 2021, doi: 10.3389/fpsyg.2021.635722.
[6] M. Połom, M. Tarkowski, and K. Puzdrakiewicz, “Warunki i perspektywy rozwoju wewnątrzmiejskiej żeglugi pasażerskiej na przykładzie Gdańska,” Pr. Kom. Geogr. Komun. PTG, vol. 23, no. 1, 2020, doi: 10.4467/2543859xpkg.20.011.12113.
[7] E. Gagatsi, T. Estrup, and A. Halatsis, “Exploring the Potentials of Electrical Waterborne Transport in Europe: The E-ferry Concept,” in Transportation Research Procedia, 2016, vol. 14, doi: 10.1016/j.trpro.2016.05.122.
[8] M. G. H. Bell, J. J. Pan, C. Teye, K. F. Cheung, and S. Perera, “An entropy maximizing approach to the ferry network design problem,” Transp. Res. Part B Methodol., vol. 132, 2020, doi: 10.1016/j.trb.2019.02.006.
[9] K. L. Rødseth, K. Fagerholt, and S. Proost, “Optimal planning of an urban ferry service operated with zero emission technology,” Marit. Transp. Res., vol. 5, 2023, doi: 10.1016/j.martra.2023.100100.
[10] M. Mańkowska, “The concept of development of passenger ferry services in the Baltic Sea Region in terms of the growing interbranch competition,” 2015.

[11] D. Szpilko and J. Ejdys, "EUROPEAN GREEN DEAL — RESEARCH DIRECTIONS. A SYSTEMATIC LITERATURE REVIEW," Ekonomia i Srodowisko, vol. 81, no. 2. 2022, doi: 10.34659/eis.2022.81.2.455.
[12] European Commission, The European Green Deal. COM(2019) 640 final, Brussels, vol. 53, no. 9. 2019.
[13] S. Mohamed Ali and A. H. Nawawi, "The social impact of urban waterfront landscapes: Malaysian perspectives," 2009.
[14] G. Pultrone, "Trieste and its port as paradigm of a renewed sea-oriented vision?," TRIA-TERRITORIO DELLA Ric. SU INSEDIAMENTI E Ambient., vol. 7, no. 1, 2014.
[15] J. Debrie and N. Raimbault, "The port-city relationships in two European inland ports: A geographical perspective on urban governance," Cities, vol. 50, 2016, doi: 10.1016/j.cities.2015.10.004.
[16] M. Tanko, H. Cheemarkurthy, S. Hall Kihl, and K. Garme, "Water transit passenger perceptions and planning factors: A Swedish perspective," Travel Behav. Soc., vol. 16, 2019, doi: 10.1016/j.tbs.2019.02.002.
[17] E. M. Kløvning, "A Study of Efficiency Regarding Port Operations on a Passenger Ferry," TransNav, vol. 18, no. 3, pp. 555–563, Sep. 2024, doi: 10.12716/1001.18.03.09.
[18] P. Gełesz, A. Karczewski, J. Kozak, W. Litwin, and Ł. Piątek, "Design Methodology for Small Passenger Ships on the Example of the Ferryboat Motława 2 Driven by Hybrid Propulsion System," Polish Marit. Res., vol. 24, no. s1, 2017, doi: 10.1515/pomr-2017-0023.
[19] M. S. Tannum and J. H. Ulvensøen, "Urban mobility at sea and on waterways in Norway," in Journal of Physics: Conference Series, 2019, vol. 1357, no. 1, doi: 10.1088/1742-6596/1357/1/012018.
[20] M. Tanko and M. I. Burke, "Transport innovations and their effect on cities: The emergence of urban linear ferries worldwide," in Transportation Research Procedia, 2017, vol. 25, doi: 10.1016/j.trpro.2017.05.483.
[21] M. Tanko, M. I. Burke, and H. Cheemakurthy, "Water Transit and Ferry-Oriented Development in Sweden: Comparisons with System Trends in Australia," Transp. Res. Rec., vol. 2672, no. 8, 2018, doi: 10.1177/0361198118782275.
[22] M. Tanko, M. I. Burke, and B. Yen, "Water transit and excess travel: discrete choice modelling of bus and ferry trips in Brisbane, Australia," Transp. Plan. Technol., vol. 42, no. 3, 2019, doi: 10.1080/03081060.2019.1576382.
[23] M. Tarkowski and K. Puzdrakiewicz, "Connectivity benefits of small zero-emission autonomous ferries in urban mobility—case of the coastal city of gdańsk (Poland)," Sustain., vol. 13, no. 23, 2021, doi: 10.3390/su132313183.
[24] E. Cabrera, R. Del Teso, E. Gómez, E. Cabrera, and E. Estruch-Juan, "Deterministic model to estimate the energy requirements of pressurized water transport systems," Water (Switzerland), vol. 13, no. 3, 2021, doi: 10.3390/w13030345.
[25] N. P. Reddy et al., "Zero-Emission Autonomous Ferries for Urban Water Transport: Cheaper, Cleaner Alternative to Bridges and Manned Vessels," IEEE Electrif. Mag., vol. 7, no. 4, 2019, doi: 10.1109/MELE.2019.2943954.
[26] V. Budnyk and K. Lernichenko, "Urban passenger water transport: Operating within public-private partnership (international research and case study)," Econ. Ann., vol. 178, no. 7–8, 2019, doi: 10.21003/ea.V178-07.
[27] P. A. Jayasinghe, S. Derrible, and L. Kattan, "Interdependencies between Urban Transport, Water, and Solid Waste Infrastructure Systems," Infrastructures, vol. 8, no. 4. 2023, doi: 10.3390/infrastructures8040076.
[28] S. Chen et al., "Coupled simulation of urban water networks and interconnected critical urban infrastructure systems: A systematic review and multi-sector research agenda," Sustainable Cities and Society, vol. 104. 2024, doi: 10.1016/j.scs.2024.105283.
[29] K. Suresh, C. Forgaci, and D. Stead, "Developing an Integrated and Contextualized Planning and Design Framework for Livable Patterns of Urbanization in Chennai," Sustain., vol. 14, no. 16, 2022, doi: 10.3390/su141610178.
[30] G. Fancello et al., "Micro urban spaces and mental well-being: Measuring the exposure to urban landscapes along daily mobility paths and their effects on momentary depressive symptomatology among older population," Environ. Int., vol. 178, 2023, doi: 10.1016/j.envint.2023.108095.
[31] S. Tahmasseby, "The Implementation of Smart Mobility for Smart Cities: A Case Study in Qatar," Civ. Eng. J., vol. 8, no. 10, 2022, doi: 10.28991/CEJ-2022-08-10-09.
[32] H. A. Tran, T. A. Johansen, and R. R. Negenborn, "Collision avoidance of autonomous ships in inland waterways - A survey and open research problems," in Journal of Physics: Conference Series, 2023, vol. 2618, no. 1, doi: 10.1088/1742-6596/2618/1/012004.
[33] A. Abođi, T. Živojinović, S. Kaplanović, and V. Maraš, "Overview and analysis of regulatory framework for the application of autonomous vessels," Tehnika, vol. 79, no. 1, 2024, doi: 10.5937/tehnika2401089a.
[34] Y. A. Ahmed, G. Theotokatos, I. Maslov, L. A. L. Wennersberg, and D. A. Nesheim, "Towards autonomous inland waterway vessels — a comprehensive analysis of regulatory, liability and insurance frameworks," WMU J. Marit. Aff., vol. 23, no. 1, 2024, doi: 10.1007/s13437-023-00316-3.
[35] A. Łebkowski and W. Koznowski, "Modeling of an Autonomous Electric Propulsion Barge for Future Inland Waterway Transport," Energies, vol. 16, no. 24, 2023, doi: 10.3390/en16248053.
[36] L. A. L. Wennersberg, H. Nordahl, Ø. J. Rødseth, V. Bolbot, and G. Theotokatos, "Analysing supply chain phases for design of effective autonomous ship technology in new transport system solutions," in Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering - OMAE, 2020, vol. 6A-2020, doi: 10.1115/OMAE2020-18715.
[37] K. Fjørtoft and E. Holte, "Implementing operational envelopes for improved resilience of autonomous maritime transport," in Human Factors in Transportation, 2022, vol. 60, doi: 10.54941/ahfe1002507.
[38] M. A. Kudrov, K. D. Bukharov, D. R. Makhotkin, and R. S. Aivazov, "Statement of the Problem of Control of an Autonomous Surface Vessel for Inland Waterways," World Transp. Transp., vol. 21, no. 3, 2023, doi: 10.30932/1992-3252-2023-21-3-2.
[39] M. M. Abaei, A. Bahootoroody, and E. Arzaghi, "Predicting future of unattended machinery plants: A step toward reliable autonomous shipping," in Proceedings of the International Ship Control Systems Symposium, 2020, vol. 1, doi: 10.24868/issn.2631-8741.2020.011.
[40] S. Krause et al., "Development of an advanced, efficient and green intermodal system with autonomous inland and short sea shipping - AEGIS," in Journal of Physics: Conference Series, 2022, vol. 2311, no. 1, doi: 10.1088/1742-6596/2311/1/012031.
[41] Y. Y. Zhang, J. Shuai, J. Billet, and P. Slaets, "Design and Build of an Autonomous Catamaran Urban Cargo Vessel," in Journal of Physics: Conference Series, 2023, vol. 2618, no. 1, doi: 10.1088/1742-6596/2618/1/012002.
[42] G. Peeters et al., "An inland shore control centre for monitoring or controlling unmanned inland cargo vessels," J. Mar. Sci. Eng., vol. 8, no. 10, 2020, doi: 10.3390/jmse8100758.
[43] Y. Gu and S. W. Wallace, "Operational benefits of autonomous vessels in logistics—A case of autonomous water-taxis in Bergen," Transp. Res. Part E Logist. Transp. Rev., vol. 154, 2021, doi: 10.1016/j.tre.2021.102456.
[44] V. V. Karetnikov, S. F. Shakhnov, and E. L. Brodsky, "Concept for Construction of Unmanned Ferry Lines on Russia's Inland Waterways," in IOP Conference Series: Earth and Environmental Science, 2022, vol. 988, no. 4, doi: 10.1088/1755-1315/988/4/042057.

[45] C. Domenighini, “Autonomous inland navigation: a literature review and extracontractual liability issues,” J. Shipp. Trade, vol. 9, no. 1, Dec. 2024, doi: 10.1186/s41072-024-00171-2.
[46] I. Popov, P. Koschorrek, A. Haghani, and T. Jeinsch, “Adaptive Kalman Filtering for Dynamic Positioning of Marine Vessels,” in IFAC-PapersOnLine, 2017, vol. 50, no. 1, doi: 10.1016/j.ifacol.2017.08.394.
[47] W. Wang et al., “Roboat II: A novel autonomous surface vessel for urban environments,” 2020, doi: 10.1109/IROS45743.2020.9340712.
[48] W. Wang et al., “Roboat III: An autonomous surface vessel for urban transportation,” J. F. Robot., vol. 40, no. 8, 2023, doi: 10.1002/rob.22237.
[49] M. Tarkowski, “Geograficzno-ekonomiczne uwarunkowania sustensywnej transformacji w transporcie – przykład elektryfikacji żeglugi promowej,” Pr. Kom. Geogr. Komun. PTG, 2020, doi: 10.4467/2543859xpkg.19.024.11545.
[50] https://www.seatech.com.pl/passanger-vessels/#1622646744420-0a0a7e91-8055 (access on line 19.10.2024)
[51] https://www.damen.com/vessels/ferries/fast-ferries/fast-ferry-4212 (access on line 19.10.2024)
[52] https://cleopatra.is/passenger-ferries/ (access on line 19.10.2024)
[53] https://www.portalmorski.pl/inne/55352-wodne-taksowki-w-polskich-aglomeracjach (access on line 19.10.2024)
[54] https://www.damen.com/vessels/ferries/modular-ferries/modular-ferry-2010 (access on line 19.10.2024)
[55] https://www.austal.com/ships/auto-express-94 (access on line 19.10.2024)
[56] https://iopscience.iop.org/article/10.1088/1742-6596/1357/1/012018/pdf, (access on line 19.10.2024)
[57] https://www.offshore-energy.biz/mf-estelle-world-first-autonomous-electric-ferry-wraps-up-trial-in-sweden/ (access on line 19.10.2024).
[58] A. Przybyłowski: “Global Trends Shaping Life Quality in Agglomerations with Particular Emphasis on Mobility in Seaport Agglomerations”. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 13, No. 3, 2019, doi:10.12716/1001.13.03.18, pp. 615-620.
[59] W. Koznowski, A. Łebkowski "Navigation of Autonomous Tug via Evolutionary Algorithms with Radar Plot Fitness Evaluation", 2025, Applied Sciences 15, no. 4: 2139. https://doi.org/10.3390/app15042139.