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Analysis of the possibilities of improving public transport in Wrocław with the use of a water tram

Abstract: The purpose of this paper is to analyze the issues related to the introduction of the water tram in Wrocław as a new means of transport that can improve traffic in the city. Examples of the functioning water tram networks in Krakow, Geneva and Hamburg are presented. The existing condition of the Wrocław Water Junction was also analyzed, including the limitations related to the measles channeling in the area of the entire junction. The possible route of the routes was presented, taking into account possible limitations. The whole thing ended with a summary and conclusions.

Keywords: Water tram; Wrocław Water Junction; Collective transport

Introduction

In addition to the most common means of transport in cities, such as buses, trams, or subways, you can find "non-standard" ones that, like the ones mentioned above, fulfill their transport function. One such means is the water bus, also known as a water taxi or ferry, which allows you to travel across waterways marked by rivers or lakes. Vehicles run on designated routes between stops according to a fixed, usually cyclical timetable. It is used in cities with a well-developed water system or in large seaports. The very idea of water trams in the world is not new and dates back to the 19th century with the popularization of steam propulsion. Most often, the water tram is a supplement to the existing transport network, which is why it is important to integrate it with other means of transport operating in the city, both in terms of infrastructure and the ticket tariff. There are many factors that can affect the success and effectiveness of this solution, including::

- the size of the water node (or the size of the lake),
- location of the water node in relation to the traffic generators in the city,
- location of stops,
- level of canalization of the water node,
- travel time,
- number of lines,
- integration with other means of transport,
- running frequency,
- other (e.g. ticket price).

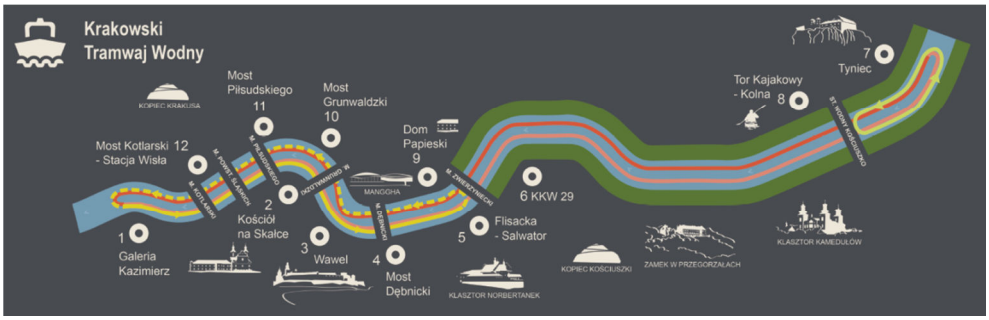
Despite the fact that Wrocław has the largest water junction in Poland in the area of the agglomeration, it is worth analyzing carefully, bearing in mind the above, whether the introduction of a new means of transport will improve traveling around the city. More

information on the potential of the Wrocław Floodway Junction can be found in the further part of the publication. At the beginning of the considerations, it is worth tracing the existing water tram network to better understand the specificity of this means of transport.

Water tram in Krakow

The Krakow Water Tram enables you to travel along the Vistula, passing the city's main tourist attractions along the way. Vehicles run during the summer season (in 2021 from June to September). The routes are served by vessels that can accommodate up to 12 passengers and a ship that can take up to 90 passengers at a time. According to the operator, the network consists of 5 lines, although there are 2 main routes and one ring route. This is because the return direction of a given route is treated as a separate line. The diagram of the network is shown in Figure **1**. The network consists of the following relationships:

- line: Galeria Kazimierz - Raftsmen - Salwator. The route within the city is covered in one direction within 30 minutes, and there are 11 stops along the way in two directions. There are 8 pairs of connections made daily. The 2021 timetable is shown in Figure **2**.
- line: Galeria Kazimierz – Tyniec (next to the Benedictine monastery). The longest route. It measures approx. 10 km in one direction, and there are a total of 13 stops along the way in both directions. A tram needs 100 minutes to cover the route between Galeria Kazimierz and Tyniec. In the opposite direction, due to the smaller number of stops, this time is 90 minutes. There is only one course in a given direction per day.
- a circumferential route constituting a scenic cruise around the abbey in Tyniec. The journey time is 30 minutes and is carried out, similarly to the longest route - once a day.



1. Scheme of the Krakow Water Tram [11]

TRASA GALERIA KAZIMIERZ — FLISACKA-SALWATOR

1	Galeria Kazimierz	10:00	11:05	12:10	13:15	14:25	15:30	16:35	17:40
2	Paulińska - kościół na Skałce	10:17	11:22	12:27	13:32	14:42	15:47	16:52	17:57
3	Wawel	10:20	11:25	12:30	13:35	14:45	15:50	16:55	18:00
4	Most Dębnicki	10:25	11:30	12:35	13:40	14:50	15:55	17:00	18:05
5	Flisacka - Salwator	10:30	11:35	12:40	13:45	14:55	16:00	17:05	18:10

TRASA FLISACKA-SALWATOR — GALERIA KAZIMIERZ

5	Flisacka - Salwator	10:30	11:35	12:40	13:45	14:55	16:00	17:05	18:10
9	Dom Papieski	10:33	11:38	12:43	13:48	14:58	16:03	17:08	18:13
3	Wawel	10:38	11:43	12:48	13:53	15:03	16:08	17:13	18:18
10	Most Grunwaldzki	10:42	11:47	12:52	13:57	15:08	16:12	17:17	18:23
11	Most Piłsudskiego	10:47	11:52	12:57	14:02	15:12	16:17	17:22	18:27
12	Most Kotlarski - Stacja Wisła	10:58	12:03	13:08	14:13	15:23	16:28	17:33	18:38
1	Galeria Kazimierz	11:00	12:05	13:10	14:15	15:25	16:30	17:35	18:40

2. Water tram timetable on the route Galeria Kazimierz - Flisacka - Salwator [11]

There is no doubt, looking at the current condition of the Krakow Water Tram, that it has been primarily a tourist attraction, not a supplement to the existing transport network in the city. This is evidenced by, for example, a small number of courses per day and its seasonality. An important aspect is also the high price of tickets. A normal ticket on the route Galeria Kazimierz - Raftsmen - Salwator costs PLN 15 (reduced - PLN 12). It is also possible to purchase a ticket for crossing any 2 stops on the route as above. for PLN 10 – regular (PLN 8 – reduced). This is a prohibitive price, taking into account the prices of public transport tickets at the level of (PLN 6 for a normal single-ride ticket [18]). The advantage is that there is no need to pay extra for transporting a bicycle. The journey time of 30 minutes alone is in no way competitive with other means of transport in the city. So far, there is also no integration in terms of the ticket tariff.

Water tram in Geneva

Geneva has a very extensive public transport network, which includes, among others: railway, tram, bus, and trolleybus network. The network is complemented by a water tram (French: Mouette), which allows moving between the two shores of Lake Geneva. The water tram network is served by 4 ports in the city center using six boats with a capacity of up to 60 seats, including two solar-powered boats [19]. An example of a ship in the fleet is shown in Figure **3**. The network consists of a total of 4 lines, i.e.:

M1 : Pâquis – Molard – Pâquis
M2 : Pâquis – Eaux Vives – Pâquis
M3 : Pâquis – Genève-plage – Pâquis
M4 : Genève-plage – Perle du Lac – Genève-plage

Boats run on a shuttle basis and have no intermediate stops along the way. The frequency of the service depends on the length of the route. On the M1 and M2 lines, vehicles run every 10 minutes, while on the M3 and M4 lines, vehicles run every 30 minutes. The timetable shown in Figure **4** shows that the water tram is not only a tourist attraction but an integral part of public transport in Geneva. This is because it significantly shortens the travel time for people who want to get to the other shore of the lake. For example, the ship needs about 10 minutes to cover the route between Pâquis - Genève-plage - Pâquis (line M3). It takes twice as long to cover the same distance with another public means of transport.

3. One of the ships serving the Geneva water bus [19]

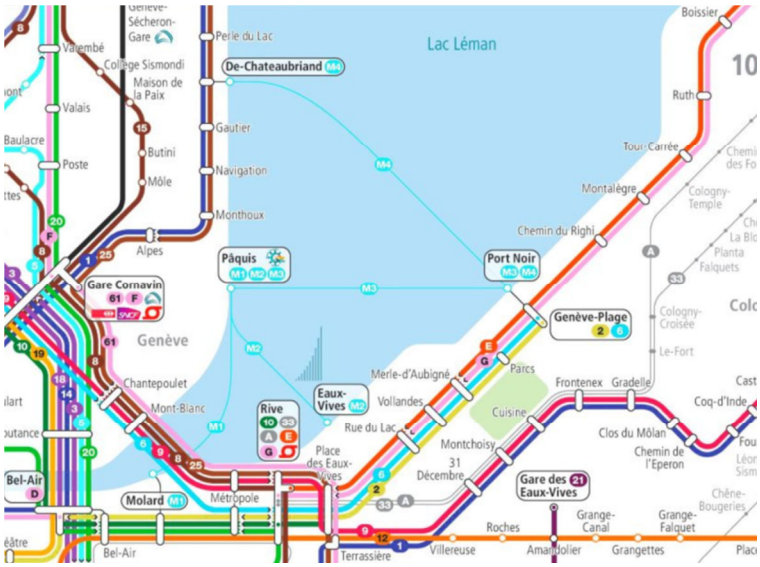
Ligne M1: Pâquis ➡ Molard

Du lundi au vendredi : Départ des Pâquis

07 h.			25	35	45	55
08 h.	05	15	25	35	45	55
09 h.	05	15	25	35	45	55
10 h.	05	15	25	35	45	55
11 h.	05	15	25	35	45	55
12 h.	05	15	25	35	45	55
13 h.	05	15	25	35	45	55
14 h.	05	15	25	35	45	55
15 h.	05	15	25	35	45	55
16 h.	05	15	25	35	45	55
17 h.	05	15	25	35	45	55
18 h.	05	15	25	35	45	55
19 h.	05	15	25	35	45	55
20 h.	05	15	25	35	45	55
21 h.	05					

4. Timetable on the M1 line on weekdays (as of January 2022) [19]

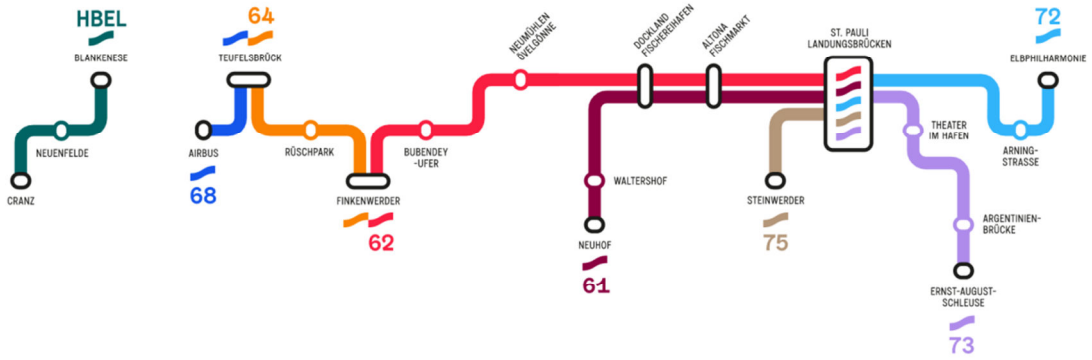
Figure **5** shows a diagram of the water tram network along with other means of transport used in the city. As can be seen, the individual water tram ports are located in close proximity to the stops of ground means of transport. This proves the good integration of the entire network, making possible transfers more convenient. In addition to the integration in terms of the location of stops, tariff integration is also important. One carrier, Unireso, is responsible for public transport in the city. This made it possible to create a common ticket tariff, which in turn allows the use of various means of transport, including the water tram, with the use of one ticket.



5. Scheme of the public transport network in Geneva in the area served by the water tram [5]

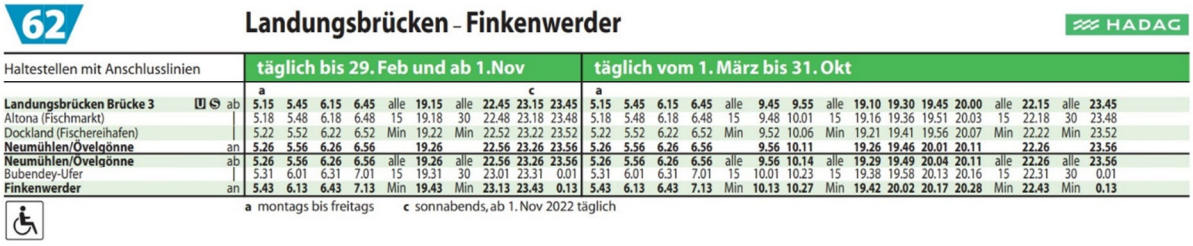
Water tram in Hamburg

Hamburg is the largest of the cities discussed in the publication with a population of over 1.85 million. The city boasts a very well-developed public transport system, which includes, among others, ferry crossings (ger.: *Hafenfähren*) running on the river Elbe. The transport operator is HADAG, which is part of the Hamburg public transport organization HVV (ger.: *Hamburger Verkehrsverbund*). Thanks to this, it was possible to create a common ticket tariff for key means of public transport within the Hamburg agglomeration [9]. The ferry network consists of a total of 8 lines, the diagram of which is shown in Figure **6**.



6. Scheme of the ferry network in Hamburg [4]

The traffic of ferries takes place throughout the year according to a fixed timetable. The frequency of the service varies depending on the line, the length of the route, and the day of the week, however, the carrier stipulates that the final travel time depends on the tides. An example timetable for line No. 62 is shown in Figure **7**. The fleet consists of 8 types of ships (26 ferries in total), which can accommodate from 114 to 250 passengers. They are powered in various ways, both with internal combustion engines and with the use of hybrid solutions.



62 Landungsbrücken – Finkenwerder — HADAG

Haltestellen mit Anschlusslinien		täglich bis 29. Feb und ab 1.Nov										täglich vom 1. März bis 31. Okt														
		a								c		a														
Landungsbrücken Brücke 3 U S	ab	5.15	5.45	6.15	6.45	alle	19.15	alle	22.45	23.15	23.45	5.15	5.45	6.15	6.45	alle	9.45	9.55	alle	19.10	19.30	19.45	20.00	alle	22.15	alle	23.45
Altona (Fischmarkt)		5.18	5.48	6.18	6.48	15	19.18	30	22.48	23.18	23.48	5.18	5.48	6.18	6.48	15	9.48	10.01	15	19.16	19.36	19.51	20.03	15	22.18	30	23.48
Dockland (Fischereihafen)		5.22	5.52	6.22	6.52	Min	19.22	Min	22.52	23.22	23.52	5.22	5.52	6.22	6.52	Min	9.52	10.06	Min	19.21	19.41	19.56	20.07	Min	22.22	Min	23.52
Neumühlen/Övelgönne	an	5.26	5.56	6.26	6.56		19.26		22.56	23.26	23.56	5.26	5.56	6.26	6.56		9.56	10.11		19.26	19.46	20.01	20.11		22.26		23.56
Neumühlen/Övelgönne	ab	5.26	5.56	6.26	6.56	alle	19.26	alle	22.56	23.26	23.56	5.26	5.56	6.26	6.56	alle	9.56	10.14	alle	19.29	19.49	20.04	20.11	alle	22.26	alle	23.56
Bubendey-Ufer		5.31	6.01	6.31	7.01	15	19.31	30	23.01	23.31	0.01	5.31	6.01	6.31	7.01	15	10.01	10.23	15	19.38	19.58	20.13	20.16	15	22.31	30	0.01
Finkenwerder	an	5.43	6.13	6.43	7.13	Min	19.43	Min	23.13	23.43	0.13	5.43	6.13	6.43	7.13	Min	10.13	10.27	Min	19.42	20.02	20.17	20.28	Min	22.43	Min	0.13

a montags bis freitags c sonnabends, ab 1. Nov 2022 täglich

7. Sample timetable for line no. 62 [4]

It is worth noting that the ferry crossing network is integrated with other means of transport (mainly with bus lines) and at almost every stop it is possible to change trains and continue the journey without much loss of time. The argument in favor of launching ferry connections is the considerable width of the Elbe, which means that there are few bridges along the river, which in turn means that the travel time from one bank to the other is significant, and the construction of new crossings is very expensive.

A common ticket tariff and the possibility of transfers make ferry crossings a very good supplement to the transport network in the city.

Analysis of the Wrocław Water Junction condition

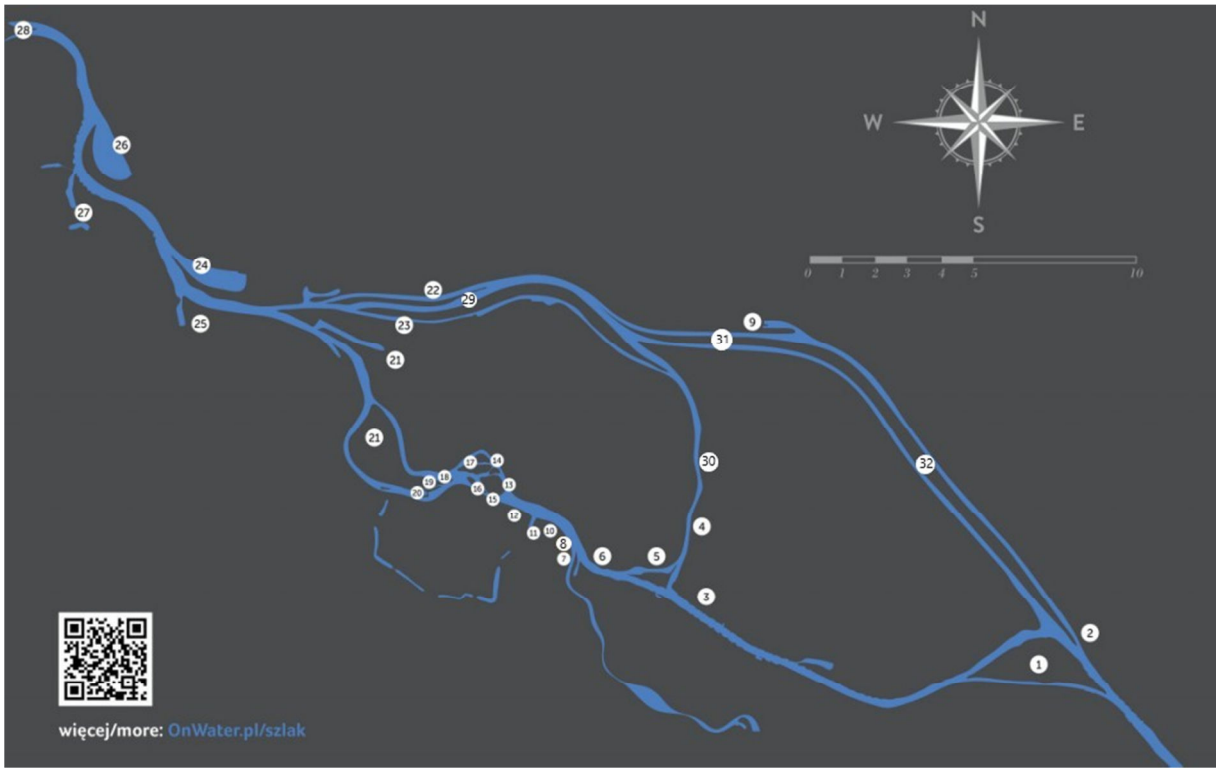
The water junction in Wrocław is one of the oldest in Poland, and the first hydro technical structures forming the Piast and Mieszczański barrage were built on the Oder River as early as the 14th century. They were used to damming water for mills and workshops. The most

dynamic period of expansion of hydro technical structures caused by the development of waterways on the Oder took place in the 18th and 19th centuries. Another important point in the development of the junction was the period after World War II when some of the facilities were rebuilt or renovated. During the second half of the 20th century, the Wrocław Water Junction stagnated in the expansion of the junction. It was only at the turn of the 20th and 21st centuries that renovations of the existing facilities were resumed [1].

Currently, the Wrocław Water Junction is the largest in Poland in the area of urban agglomeration, as well as one of the largest in Europe. In its area, there are numerous hydro technical structures as well as engineering structures and they are:

1) Opatowice weir, Opatowice lock,
2) Bartoszowice weir, Bartoszowice lock,
3) ZOO marina, Zwierzyniecka footbridge,
4) Zwierzyniecki Bridge,
5) the Szczytniki lock,
6) the Wyspiański coast,
7) the mouth of the Oława River, the port of the mouth of the Oława River, the Oławski Bridge,
8) the Grunwaldzki Bridge, the first house on the water in Poland,
9) Zacisze shipyard,
10) Maria and Lech Kaczyński Boulevard, Peace Bridge,
11) Gondola bay,
12) Xawery Dunikowski Boulevard,
13) Piotr Włostowic Boulevard,
14) Młyńskie bridges, Tumski bridge,
15) Piaskowy Bridge, Tourist Marina,
16) the Piastowska lock, the bridge and the weir of St. Matthias,
17) Słodowa footbridge, Żabia footbridge,
18) University Bridge,
19) Mieszczańska lock, Pomeranian bridges,
20) The Bourgeois Barrage, hydro power plants,
21) City Port, river repair shipyard,
22) Różanka lock,
23) the Psie Pole barrage, the City Lock, Osobowicke bridges,
24) Millennium Bridge, Barek I winter camp
25) the port of Popowice,
26) Barek II winter camp,
27) Emperor Wollheim Shipyard and Port,
28) the Rędzin barrage, the Rędzin locks,
29) the Różanka barrage, the Trzebnickie bridges,
30) Szczytnicki Bridge,
31) navigation canal, Zacisze sluice, Jagiellońskie bridges,
32) Chrobry's bridges.

Figure **8** shows the location of the above facilities on the Wrocław Water Junction plan.



8. Wrocław Water Junction - hydrotechnical facilities, edited drawing [2]

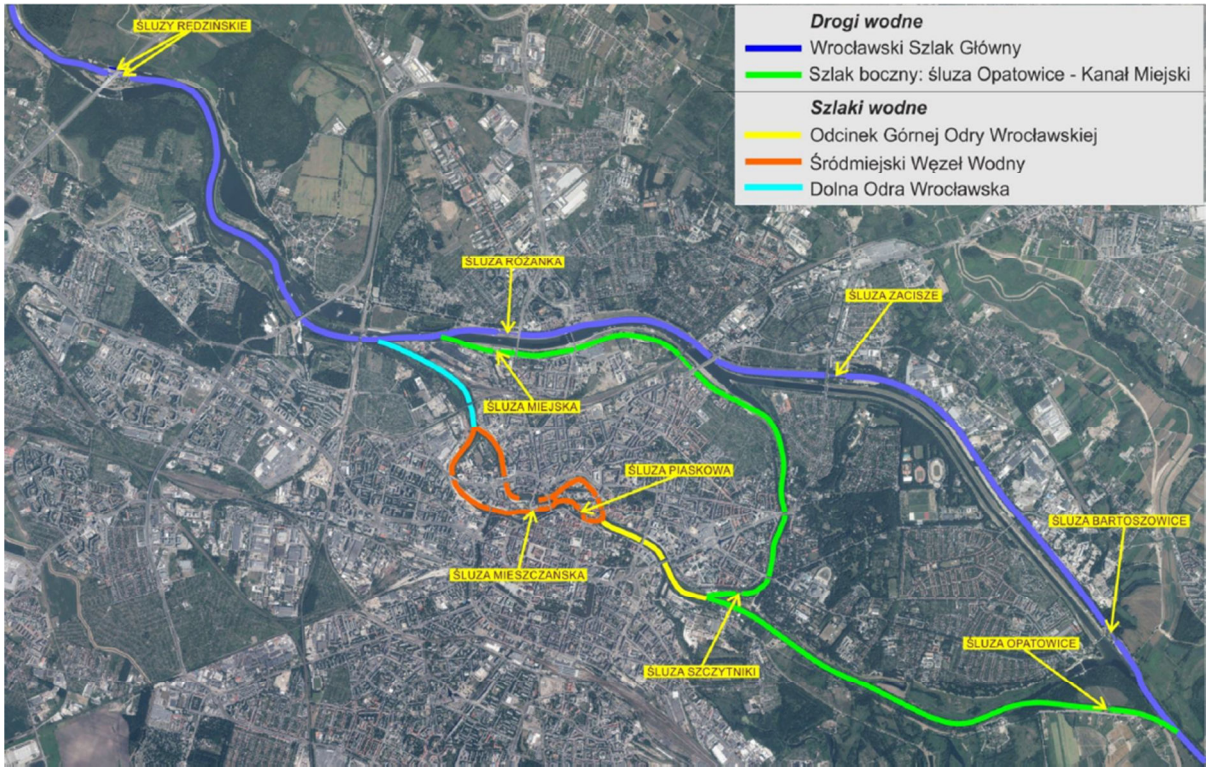
Inland waterways are divided into classes: from the lowest Ia to the highest Vb, where classes from Ia to III are of regional importance, and from class IV onwards are of international importance [18]. Affiliation to a given class is determined by such parameters as the width of the shipping lane, transit depth, and the radius of the arc of the shipping lane axis. Currently, there are two waterways and three waterways at the Wrocław Water Junction, which are shown in Figure **9** [6].

Waterways can be included:

- Wrocław Main Trail, 10.70 km long, including a 7.40 km class III navigation channel,
- side route: lock Opatowice - City Canal, 13.10 km long, class II,

while the waterways may include:

- the section of the Upper Odra Wrocławska, 1.20 km long,
- Śródmieście Water Junction with a length of 2.80 km looking at the South Oder with the Piastowska and Mieszczańska locks and a length of 2.50 km looking at the North Oder with sections and shipping branches, class Ia,
- Lower Odra Wrocławska, 1.50 km long.

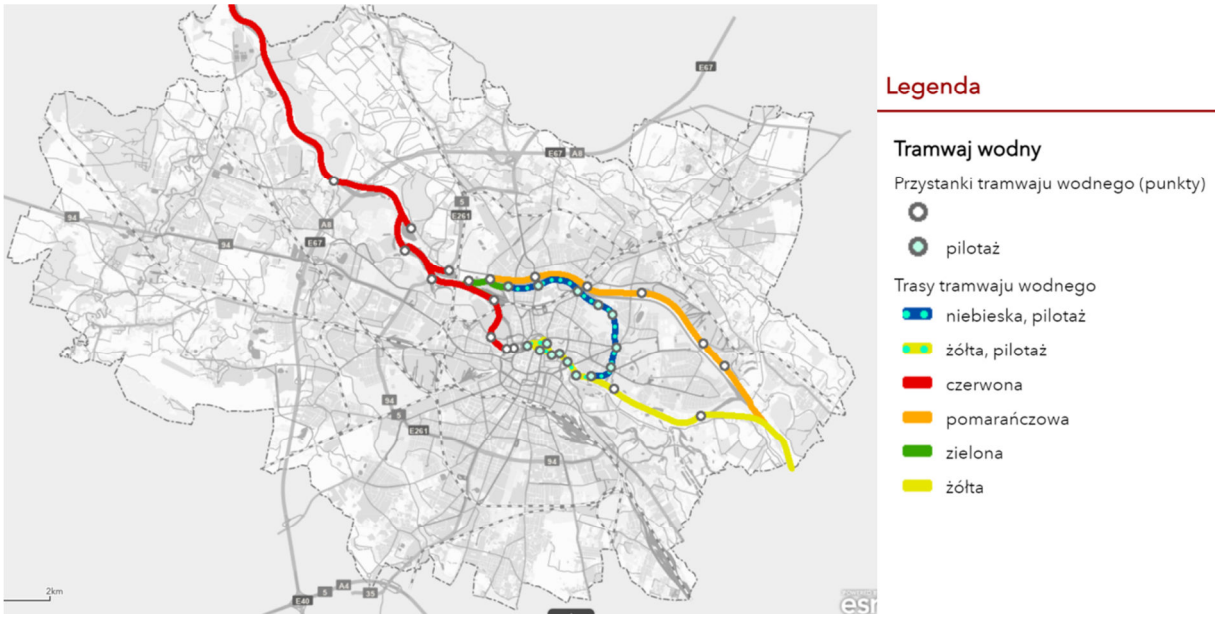


9. Waterways and water routes of the Odra River within the Wrocław Water Junction [14]

Currently, after the renovation in 2015, the Rędzińskie locks marked in Figure 8 No. 28 are of class IV parameters, and the other facilities meet the requirements for classes Ia, II, and III. With the appropriate reconstruction of individual engineering structures by changing their technical parameters, it is possible to adapt the Wrocław Main Route to class IV. The waterway of the Śródmieście Water Junction is class Ia due to the Mieszczańska Sluice, which is 42.8 m long, 5.3 m wide, and damming up to 5.65 m.

Analysis of water tram routes in the city of Wrocław

In 2019, the Wrocław City Hall began planning the launch of the first pilot water tram line [7, 8]. The assumptions of the project are passenger ships that will run every day, and the stops along the route would be located at important points in the city, i.e. Wrocław University, Wrocław University of Science and Technology, and the ZOO. It is a proposal as an "alternative" to the current public transport in the city (trams and buses). The aim is to relieve public transport by using a new, more ecological means of transport, which is to be a water tram. The routes initially designated by the Wrocław City Hall are shown in Fig. **10**.



10. Proposed water tram routes by the Wrocław City Hall [3]

A total of 6 routes have been proposed, including two pilot ones [3], tj.:

- the "red" line: from the Wrocław I Hydroelectric Power Plant, will lead up the river, passing Kępa Mieszczańska from the west, then through the City Port and the vicinity of the Millennium Bridge, ending the route in the Maślice housing estate,
- the "yellow" line: from the University Bridge and the Słodowa Island to the Szczytniki lock, the ZOO and the Zwierzyniecka footbridge,
- the "blue" line: it is a continuation of the "yellow" route - from the Zwierzyniecki bridge, then along the Old Oder leading to the City Canal to the Osobowickie bridges and the City Lock,
- the "green" line: will connect the blue and red routes, from the Osobowickie bridges and the City Sluice to the City Port,
- the "orange" line: from the Różanka canal, through the Trzebnickie bridge and the Warszawskie bridges, the shipping channel to the vicinity of the intersection of Marco Polo from and Ferdinand Magellan Streets.

The proposed course of individual lines was dependent on the existing hydro technical facilities located at the junction, mainly through numerous sluices.

At the turn of November and December 2021, social consultations were organized in the form of an online survey, in which residents were asked for their opinion on the course of the above-mentioned. routes [12]. Unfortunately, at the time of publication (i.e. April 2022), the report with the results was not published.

Evaluation of the possibility of launching a water tram in Wrocław

The idea of launching water trams has quite a lot of potential in Wrocław, if only because of the size of the water junction and its location on the city map. It runs largely through the city center and is surrounded by many major science, tourist destinations, and workplaces. Unfortunately, along with great potential, there are also a few problems and limitations to be reckoned with. As can be seen in Figure 8, there are numerous weirs on the Oder, and consequently, it is necessary to overcome locks. The passage time of the ship through the lock is from 8 to even 30 minutes, depending on the technical parameters. For the purposes of this study, it can be assumed that the average flow time through the sluice is approx. 12 minutes. This is a long time, taking into account the distance that can be covered in this time by using

other means of transport available in the city. Another aspect that is worth paying attention to is the fact that the operation of water trams in the winter may be severely limited or even impossible [13]. During the winter, due to the freezing of the river, the ship cannot run on some sections due to the locks being closed. In the event of freezing of the entire section of the river, transport by water is completely impossible. The next problem is the equipment of the ship itself and its operation. Assuming that the ships will carry from 60 to 90 people, this causes additional formal and legal problems. Required equipment should be taken into account, i.e. the number of necessary life rafts for every 10 people, the number of life jackets for each person, or lifebuoys. It is also important to remember about the necessity of having qualified staff operating this type of vehicle. The basic staff includes the ship's manager, who must be authorized to operate the ship's mechanical propulsion devices, and at least 3 crew members (chief seaman, seaman, junior seaman) [15, 16]. In the case of a tram and a bus, only one person is sufficient to operate it. In addition, the qualification to drive a ship is much more difficult to obtain, and the training process itself is much longer than in the case of, for example, training for a tram driver. All this generates additional costs at the beginning of the investment and during operation (ship salary). In addition, the equipment on board must be inspected every 5 years [17].

Analyzing the statement that the water tram is an ecological means of transport, and it is considered as such, it is not entirely true. If the ship is powered by a combustion engine, it still pollutes the environment. The issue is different in the case of electric propulsion, but the much higher cost of the ship should be taken into account. The last thing worth paying attention to is the issue of the tariff for the ride. Looking at the example from Krakow (see point 2), the price of one normal ticket is PLN 15, while the discount ticket is PLN 12, and the transport offer is not integrated with other means of public transport in the city, even in terms of a common ticket tariff.

Summary and Conclusions

Despite the fact Wrocław has a well-developed water hub, the launch of water trams may not bring the expected results in terms of faster movement around the city, especially in the city center. Due to the long travel time caused by numerous locks on the river and higher prices than in the case of traditional public transport in Wrocław. On the routes proposed by the Wrocław City Hall, the water tram is only used for tourism.

However, in the authors' opinion, launching a new means of transport may be justified and constitute a good complement to the existing transport network, but only under certain conditions. Analyzing the existing examples, it is possible to deduce under what circumstances launching such connections is justified. First of all, this solution is recommended when the line is laid across a river or lake, as is the case, for example, in Geneva. It is also important that the frequency of vehicle runs is adapted to the needs of residents, preferably using a cyclical timetable. You should also remember about integration with other means of public transport in the city. Therefore, it is worth allowing travelers a comfortable transfer. The attractiveness of this solution will be further enhanced by integration in terms of a common ticketing tariff, as is the case, for example, in Geneva and Hamburg.

Therefore, it is worth considering launching a water tram in order to cross the Oder River, from one bank to the other, just as cable car connections are currently being implemented on the campus of the Wrocław University of Science and Technology, the so-called Polinka. The issue of selecting such places together with the analysis of the legitimacy of such a solution should be the subject of more detailed analyses, and the results of the public consultations may additionally help in designing routes.

Source materials

[1] Dziubańska A., Weintrit A., artykuł pt. „Wrocławski Węzeł Wodny", Logistyka 3/2014
[2] http://www.onwater.pl/szlak/
[3] https://gazetawroclawska.pl/tramwaj-wodny-we-wroclawiu-ktoredy-poplynie-mapa-trasy/ga/c1-15925231/zd/53281719
[4] https://hadag.de/de/
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[9] https://www.hvv.de/
[10] https://www.mpk.krakow.pl/
[11] https://www.tramwajwodny.net.pl/
[12] https://www.wroclaw.pl/
[13] Informacja Żeglugowa na rzece Odrze wg stanu na dzień 01.02.2021 r. na godz. 6:00 UTC (7:00 CET)
[14] Kostecki S., Rędowicz W., prezentacja pt. „Wrocławski szlak żeglugowy", Politechnika Wrocławska, Wydział Budownictwa Lądowego i Wodnego, Katedra Geotechniki, Hydrotechniki, Budownictwa Podziemnego i Wodnego
[15] Międzynarodowa Organizacja Morska – IMO, Międzynarodowa Konwencja o bezpieczeństwie życia na morzu, 1974 SOLAS Tekst jednolity, 2015, Druk 3833 cz. II z 2
[16] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 20 listopada 2014 r. w sprawie kwalifikacji zawodowych i składu załóg statków żeglugi śródlądowej
[17] Rozporządzenie Ministra Infrastruktury z dnia 5 listopada 2010 r. w sprawie wymagań technicznych i wyposażenia statków żeglugi śródlądowej oraz upoważniania podmiotów do wykonywania przeglądów technicznych statków
[18] Rozporządzenie Rady Ministrów z dnia 7 maja 2002 r. w sprawie klasyfikacji śródlądowych dróg wodnych
[19] www.mouettesgenevoises.ch