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River Tramway – an Alternative Solution for Sustainable Passenger Urban Transport System

Key words: transport, sustainable, alternative, design

The development of sustainable transportation means and systems is one of the European policies. Different criteria are taken into consideration to find an optimum solution when urban transport is investigated – in both traditional and innovative technical solutions.
In the paper an alternative proposal to inland systems is proposed and the concept of design solutions is presented as well. The proposal is addressed partly to the local waterways in Szczecin and Western Pomerania region and is based on a sustainable passenger traffic analysis. It may also be interesting for application in the conditions of other cities and regions – Wroclaw, Dresden and Praha.

Żegluga śródlądowa w komunikacji miejskiej jako czynnik zrównoważonego rozwoju transportu

Słowa kluczowe: transport, zrównoważony, alternatywny, projekt

Rozwój środków i systemów transportu zrównoważonego stał się jedną z naczelnych dyrektyw Unii Europejskiej. Badania nad środkami transporu miejskiego, w dwóch aspektach – tradycyjnym i innowacyjnym, wymagają wzięcia pod uwagę wielu różnych kryteriów i poszukiwania optymalnego rozwiązania.

W publikacji przedstawiono propozycję alternatywnego wykorzystania dróg śródlądowych w celach transportu miejskiego. Zaproponowano wstępną koncepcję rozwiązania projektowego.Rozwiązanie przystosowane jest do warunków panujących na lokalnych drogach wodnych Szczecina i rejonu Pomorza Zachodniego i spełnia warunki uzyskane z analizy zrównoważonego transportu pasażerkiego. Rozwiązanie to może stanowić ciekawą alternatywę również dla innych miast – Wrocławia, Drezna i Pragi.

Introduction

Municipal transport is an important and decisive element influencing an effective operating of the city. That fact, taken into consideration, should facilitate the city's development as it ensures an accessibility to workplaces, schools, health care institutions as well as other life and cultural services.

An increasing number of inhabitants of large agglomerations, which is connected with intensive growth and dissipation of urban areas, calls for new and higher requirements for municipal transport. Such a transport should become an alternative and reasonable solution for increasing individual transportation. Intensification of individual transportation causes congestion (particularly in the cities) and complicates effective and fast movement on crowded streets. That forces additional investments in the infrastructure of the city. Moreover, such a situation destabilizes (destabilization factor) a balanced transport.

Due to the elaborated definition (by OECD), sustainable transport means "harmless to human health or ecosystems, satisfying the needs of movement of humans and goods, and utilizing renewable sources below their regeneration possibilities or utilizing non-renewable sources below development possibilities of their renewable substitutes" [1].

Hence, a superior objective of the balanced transport following from that definition is meeting the demands of transportation market at the lowest environmental costs as possible. Limitation of growth dynamic of individual transport to gain an objective of increase of collective transport is mainly dependent on passengers' preferences concerning the quality of transportation services. The preferences contain: comfort, time, cost and safety of traveling.

In most cases collective transport is realized by land transportation means:

- ground- and underground railways,
- buses,
- trams,
- trolley-buses,

The Polish agglomerations, located at superficial watercourses, sporadically utilize water-born transport as a complementary to the existing municipal transport. The situation is typical even where the conditions are in favour of such actions.

Demographic and hydrographic analysis of Szczecin City

Szczecin is a typical example of non-utilized possibilities of water-borne transport. Number of inhabitants is more than 400.000, and the area inside of city borders is 307 km2. The functional – spatial structure of the city is formed in the natural conditions of the mouth of the Odra River. The Old Town, the city centre (downtown) and 60% of the city infrastructure is located on the west side of the River. The east side concentrates about 25% of potentials. Both sides are separated by the wide valley of the Odra River. A considerable amount of industrial potential and number of workplaces are localized in the valley. Up-to-date urbanization process causes dynamic growth of the city west- and south-westward. Therefore, actual urban scheme of Szczecin makes it necessary to travel between the western and eastern sides of the Odra River. 32% of inhabitants live close to the river. The demographic situation is presented in Fig.1 and illustration of Szczecin waterways complex in Fig.2.

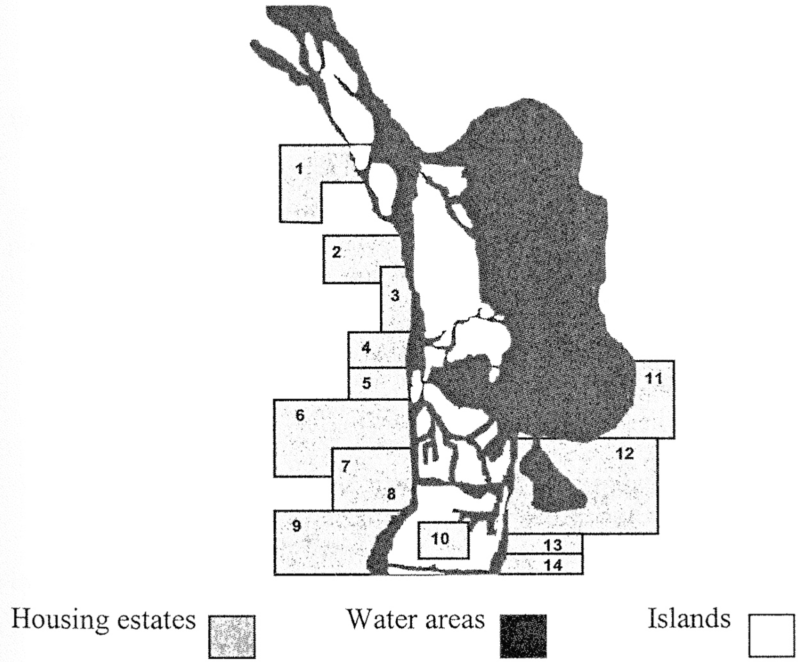

Fig. 1. Localization of Szczecin settlements over the Odra River bank: 1 – Skolwin, 2 – Gocław, 3 – Golęcino, 4 – Drzetowo, 5 – Grabowo, 6 – Śródmieście (Midtown) – Stare Miasto (Oldtown), 8 – Nowe Miasto (Newtown), 9 – Pomorzany, 10 – Międzyodrze, 11 – Załom, 12 – Dąbie, 13 – Zdroje, 14 – Podjuchy

Rys. 1. Rozmieszczenie dzielnic Szczecina na brzegach Odry

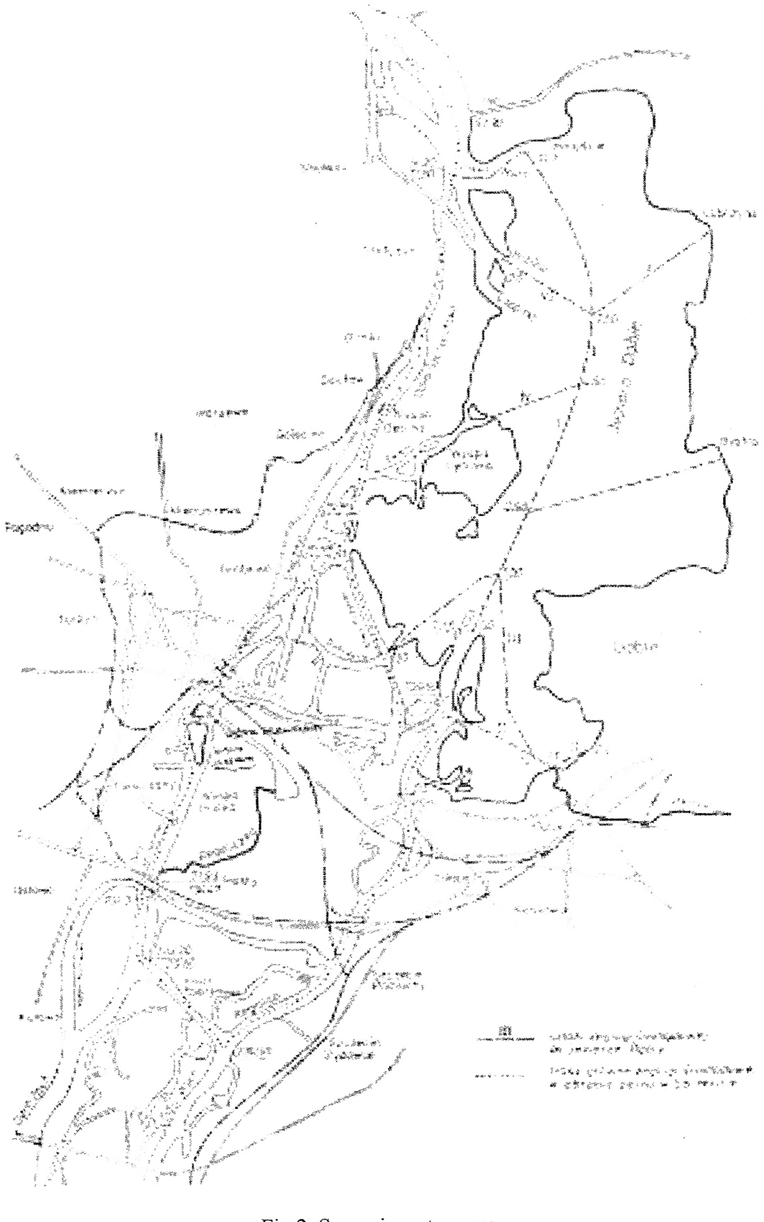

Fig.2. Szczecin waterways
Rys. 2. Drogi wodne Szczecina

Two routes connect the western and the eastern parts of the agglomeration, and both are used by municipal transportation means: buses and trams. The lengths of routes led over waterways complex are from 10 to 20 km. Szczecin waterways are not used for alternative transport service so far, with the reasons as follows:

- long duration of transport if typical ships/ferries with speed of 15km/h are applied,
- expensive service which is caused by:
  - operational costs,
  - diversified number of passengers at cyclic operations.

It can be concluded that:

- application of ships/ferries operating at speed of 30-40km/h is necessary to keep service time comparable and competitive to land transportation means operating on similar routes (length),
- application of energy-saving solutions which will result in price competition with other public and individual transportation means.

Proposal of technical solutions

Taking into consideration the costs and time of voyage, it can be found 'a priori' that searching for simultaneous minimum of these both values is not possible in the case of typical/traditional inland waterway ships (as solutions). It is, however, possible to find a solution close to the optimal if:

- Vessels used in service fulfill the condition of energetic minimum (E_{min}), which is determined by length of ship at already defined and constant speed (v):

$$E_{min} = f(L, v = \text{const})$$

- Energetic systems of these ships will utilize elements of non-conventional power sources such as solar energy sources or others.

Based on the results of scientific investigations it can be concluded as follows:

1. The application of photo-voltaic cells as a solar energy converter working with efficiency of 0.1, and driving propulsion system in real-time (without accumulation of energy), makes it possible to propel a double-hull passenger ship having the following particulars:

   - length $L = 25.00$ m,

- breadth $B = 9.00$ m,
- draught $T = 1.00$ m,
- speed of 12 km/h,
- 100 passengers capacity.

The speed of the ship in this case is comparable to classical, displacement-type craft solutions, but costs of energy in operational and other external costs (e.g. environmental) approach zero.
Obviously, the application of high-efficiency photo-voltaic cells (see: solar energy systems applied in space craft) will result in higher speed of the vessel.

2. The case of a ship operating at higher speed, but still fulfilling the condition of energetic minimum, results in increased length and number of passengers. Assuming speed of 20 km/h the particulars are:

   - length $L = 45.00$ m,
   - breadth $B = 9.00$ m,
   - draught $T = 1.00$ m,
   - 200 passengers capacity.

Recent know-how on the energetic systems makes it possible to apply hybrid-type systems composed of photo-voltaic cells (1/3 of total power) or fuel cells (2/3 of total power). Such solution minimizes all external costs but will not avoid operational costs, e.g. consumption of hydrogen fuel (this can be replaced with the solar energy system of efficiency equal to 0.3).

3. A propulsion system composed of exclusively fuel cells is able to drive a vessel up to the required speed of 40 km/h. If the condition of energetic minimum is fulfilled, the ship can reach a length of 100 m and a capacity of 450 passengers.

4. Abandoning the condition of energetic minimum and limiting the length of the ship to achieve an objective of a required speed can result in the application of fuel cells as the only energy source. External costs will be minimized in the case when the cost of fuel increases significantly in comparison to the ship having energy-saving length.

The example of a vessel having a hybrid propulsion system is presented in Fig.3 [2]. The practical application of each of the presented solutions in the inland waterway passenger service is an alternative to the existing municipal as well as individual transport. It concerns agglomerations located at inland waterways and distributed inside the city area or divided by waterways. It is necessary that living, service and industrial areas are located in the neighborhood of the river (waterway).

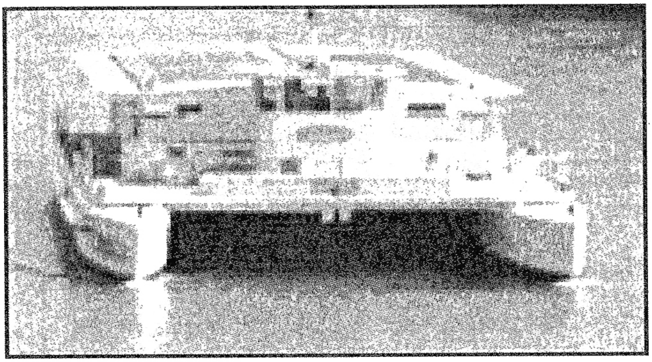

Fig. 3. Hybrid diesel-electric driven ship

Concept vessel design

Following the research results on Szczecin waterways and demands expected on innovative transport solution, the concept design of a river tramway has been elaborated. This is a preliminary design and should not be considered as final from the topological and functional point of view. The proposition is a basis for further and more detailed design works.

The vessel is designed to fulfil its main feature of transportation of passengers as well as some bicycles, prams and wheelchairs in the agglomeration area located at waterways (e.g. Dresden, Prague, Wrocław, Szczecin, others). The river tramway is going to be an alternative transport solution in big agglomerations instead of traditional, road-going means as buses and cars in particular. The idea is to shift a part of passengers to the new system of river tramways.

The vessel is going to follow the requirements expected from a sustainable system. That leads to the application of environmental friendly solutions. Moreover, the competitiveness to existing systems exerts pressure on the vessel's service parameters such as speed, manoeuvrability and costs.

The presented solution is meeting the particulars presented in proposal no.2. Therefore, the particulars are as follows:

Table 1

Main particulars of river tramway concept design

No.	Description	Symbol, unit	Value
1	2	3	4
1	Length	L_{PP}, m	45.00
2	Length overall	LOA, m	47.86
3	Breadth, moulded	Bm, m	9.00
4	Breadth, max.	Bmax, m	9.24
5	Height	H, m	5.00
6	Draught, design max.	T, m	1.00
7	Depth	D, m	4.00
9	Freeboard	m	0.90
10	Block coefficient	CB	0.82
11	Light weight	M, t	132.84
12	Number of passengers	n	200
13	Speed	V, knots	11

The vessel is a double-hull ship, where the hulls contain tanks for fuel, fresh water and others necessary for living and driving systems of the ship. The vessel's arrangement contains five sections: two engine rooms, two bridges and one, continuous passenger area in amidships. The ship is propelled by two azipods.

The arrangement of two engine rooms and bridges is enforced by time saving requirement, manoeuvrability, speed and safety. Height of the vessel is limited by accessible clearance under bridges in Szczecin (max.4 m).

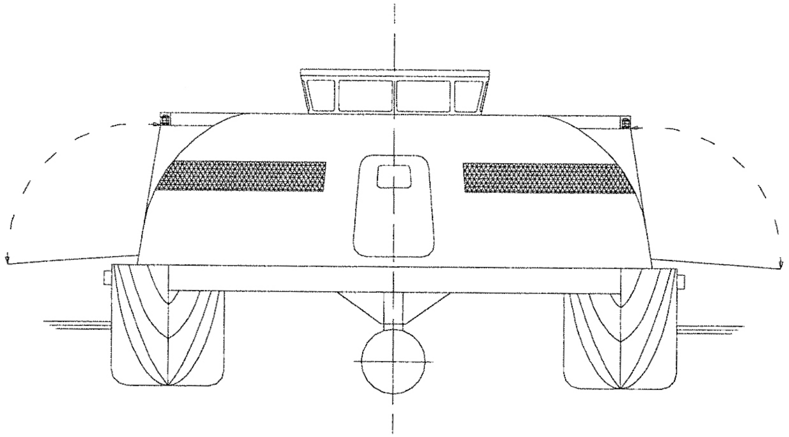

Fig. 4 – Front view of the river tramway

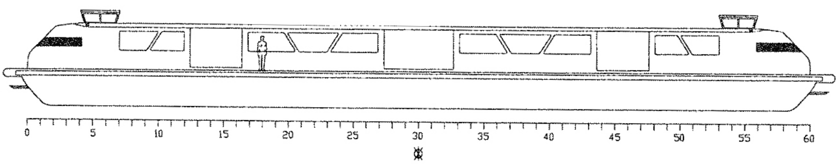

Fig. 5 – Longitudinal section

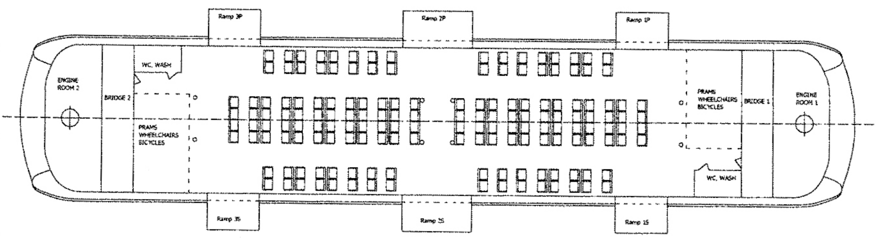

Fig. 6 – General arrangement, deck

The presented design offers 160 seats, abt.40-50 standings, 35 m^2 of room for bicycles, prams or wheelchairs, and about 60 m^2 of free area. There are two WC's at fore and aft.

Quick loading and unloading is ensured by three ramps installed on both sides. Mid ramps are wider than others as predicted to be used by passengers (pedestrians). Four others give a good access to areas for bikes.

The crew is predicted to be composed of two men: captain and engineer. There is no room designed for crew except bridges as the vessel is going to operate similarly to buses.

Engine rooms are located on both ends and are accessible by external, front doors. This solution ensures the ship`s operating in case of one engine failure and keeps the shortest connection with propellers. Moreover, screws installed on both ends of the ship allow quick and easy manoeuvres of the double-hulled structure.

The design still needs to be revised from driving system point of view (required room plus externals) as well as mooring system (fully- or semi-automatic, stiff, no ropes), ship abandoning system and navigation.

Concluding remarks

The analyses have been carried out in many countries and have proven that the radical actions on transport services, approaching to sustainable systems, will give a positive result in 25-35 years.

The preliminary phase of the sustainable transport policy should find an optimal compromise between costs and benefits (from the environmental, social and industrial point of view). Three priorities can be indicated here:

- actions to rationalize demands on transport services,
- shifting the employees of already existing transport companies to new, environmental-friendly enterprises,
- application of new, clean technologies and techniques as well as systems / devices of direct environmental protection.

The overall aim of rational transport policy is to get a level of sustainable system with respect to technology, space, industry, society and environment in the conditions of developing countries.

The technological aspect of the sustainable system means to search for parameters related to flow capacity, quality and safety.

The spatial aspect applies to localization of transport means due to site planning. It also covers selection of functions, localization and planning with respect to rational traffic management and minimization of transport labour.

The industrial aspect has two meanings. The first concerns macro scale - lack of limitations on the economic growth; while the second to sector scale - transport development as a part of economy, market protection and competition.

The equivalent access to mobility is a main goal of social aspect. It also includes an equal accessibility to different areas of the city, reduction of accidents and risk, and limitation of negative effects on citizens.

The ecological / environmental aspect means widely understood direction of the sustainable transport development oriented to protection of non-renewable sources of natural environment.

Balancing of the elements listed above comprehends a policy of impact on system users. That leads to configuration of mobility, division of traffic into different transport means, fitting of timetables in the system. All the items are formed without any exceeding of limitations (given in the presented aspects) and fulfill needs of mobility inside the agglomeration [3].
In the context of sustainable transport, the development of inland waterway transport, considered as a common part of the municipal transport, should be recognized as consistent to the overall objective of the modern transportation policy, and can be expected to yield positive results in a relatively short time. Any other solution is related to high external costs where the main expenses are:

- terrain-demanding infrastructural investments including bridges,
- intensification of pollutions as a result of heavy land traffic.

It can be expected that government subventions for waterborne transport will be granted, which is actually recommended in the EU directives on development of the sustainable inland waterway transport. This will result in reasonable and competitive prices to be paid by final customers.

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