Methodology for Choosing an Appropriate Inland Vessels as a Floating Distribution Centers

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Abstract

The primary goal of this paper is to propose a methodology for the choice of an appropriate vessel type under the specific condition of floating distribution center. The right choice of the appropriate type of vessel has a fundamental influence on the long-term success of city logistic projects with water transport. In this paper, we propose a methodology for vessel choice according to its inner layout and technology of handling. The possibility of an application in practice will be defined for each option.

1 Introduction and literature review

Permanently growing volume of road transport in the European agglomerations causes many problems, which can not be solved only within particular components of the transport system. Principally it is about solving of negative impacts of road transport on the overall traffic situation in the city and on pollution of the environment with emissions and noise. The capacity of roads and streets in the city quite often doesn't correspond to today's demand. Overload of roads leads to collisions between requirements of passengers and cargo transport (both dynamic and static) and pedestrians. [2,7,8]

Today's solutions of city transport services are based on an appropriate combination of partial measures and technologies. As a traditional solution of transport regulation and organization, for example, a creation of the one-way street system, regulations of parking, dedicated route lines, speed restrictions, traffic bans or restrictions for a specific type of vehicle can be mentioned. [7, 8] As complex solutions can be added to these measures for example inclusion of distribution centres (city terminals) into logistic chains for city service, support for alternative kinds of transport, the use of unified transport and handling units and the use of telematics and information technologies. The inclusion of distribution centres into the logistic system for city service enables mainly the better supply arrangement with an opportunity for vehicle routing problem optimization and vehicle fleet optimization. At the same time, it offers the option for the transfer of a part of the last mile deliveries to available alternative kinds of transport i.e. tram, water transport or bicycle transport. The water transport as the only one of the above-mentioned kinds of transport has (except for transport function) the potential to fulfill a function as a floating warehouse and/or distribution center.

Several authors have proposed and used the multilevel models of transport service in urban areas. These models allow and support decisions for a change of transport type to the most environment-friendly type in the urban areas. Jacyna in [5] proposes a multistage distribution system with the use of cargo tram. Krampe in [7] mentions the possibilities and benefits of using logistics centers, which are situated on the periphery of the city, for the distribution of goods and reverse logistics. He suggests the use of different types of transport. However, he describes the use of water transport (inland vessels) only for the long haul and not for the direct service in the city centers. Janjevic in [6] presents specific possibilities of the use of the water transport in the city centers e.g. for supplying, distribution of parcels or waste logistic. He also describes the importance of cooperation in the form of Public Private Partnership. Analytical and case studies (e.g. [1, 2, 3, 6]) show that the choice of suitable vessel type is one of the key factors for the achievement of desired effects (reduction of emissions and number of trips with road cargo trucks). According to the mentioned studies the reduction of emissions can be between 25 – 75 % for diesel vessels and 94 – 100 % for electric vessels. The savings in road distance can be expressed in hundreds of thousands of kilometers according to the area. The vessel is the key investment. The right choice of the vessel type is necessary for the sustainability of the whole system and can substantially affect its success in the future. [6]

The theoretical basis for solving the issues related to the choice of appropriate type of transport mean in the case of replacement older one can be found in [4, 8] as a mathematical theory of renewal. For the solution of new transport mean choice are rather used economical models in practice. Cost simulations can be found e.g. in [10], where the distribution model with an electric vessel in Belgium was used.

2 Input conditions

2.1 Inland vessels in city logistics: European cities

In the context of European countries, inland vessels are used today as floating warehouses very rarely. In table 1 European cities are displayed, which use (or used) vessels for city logistic services.

The basic requirement for the usage of vessels in city logistic is a navigable waterway. Parameters of waterway – mainly the size of locks and vertical bridge clearance – determine the maximum size of the vessel for the specific waterway. Examples mentioned in table 1 show the variety of types of vessels used. These vessels are based on traditional types used on the specific waterway. Parameters of vessels in the specific systems can be very different including the capacity of cargo space.

The distribution model which is used has an influence on the choice of the appropriate type of handling unit, the layout of the cargo space in the vessel and the way of handling. The connection to existing infrastructure is very significant because its installation in city centers is both very limited and - in the case of water transport - very expensive. Possible distribution models must be formulated and generalized before solving the vessel choice problem.

Table 1: European cities with city logistic systems using inland vessels

City	Initiative	Distribution model	Vessel type	Loading capacity	Unit load	Material handling equipment
Paris	Vert Chez Vous	package delivery	diesel-propelled ship	363 t	palette bike	hydraulic crane
	Franprix	distribution of food products to local businesses	diesel-propelled pushboat with barge	48 containers	container	reachstacker
Utrecht	Beer Boat	distribution of food and drinks to local businesses	electric-propelled ship/newbuild	18 t (40-48 rolltainers)	rolltainer	hydraulic crane
Amsterdam	DHL	mail and package delivery	diesel-propelled ship	30 m^3	package bike	manually
	Mokum Mariteam	delivery of goods and waste collection	electric-propelled ship/newbuild	85 m^3	container	hydraulic crane

2.2 Definition of city agglomeration service models with use of inland vessels

The usage of vessels in city service is more suitable for large agglomerations. This can be confirmed according to the examples in table 1. The Netherlands have the highest density of inland waterways in the Europe. Relatively extensive networks of canals are a part of the transport system in Amsterdam and Utrecht. This network is an excellent precondition for the use of vessels in the city centers, it is also possible to use only one waterway (without canals), which serves in combination with other kinds of transport as a backbone.

In this case, the vessel doesn´t serve as a mode of transport only, but it is simultaneously a warehouse (e.g. waste collection, supplying) and/or a distribution center (parcels sorting and their delivery). Models of city agglomeration services with the use of water transport can be divided into two groups:

Models with direct customer service

In this model, the vessel usually starts its way from the port (distribution or logistic center) located on city borders or in near vicinity and serves customers, which are located directly on the bank of the waterway (Figure 1). The vessel returns back to the starting point from the last customer.

As advantage can be identified the direct customer service without the necessity of transshipment on follow-up transport. The relatively small set of potential customers and limited possibilities of handling according to the infrastructure can be identified as disadvantages.

This system can be used in cities with a more extensive network of waterways and with a higher concentration of potential customers located directly on the waterfront. It is, for instance, suitable for supplying (restaurants, bars, retailers) or for waste collection.

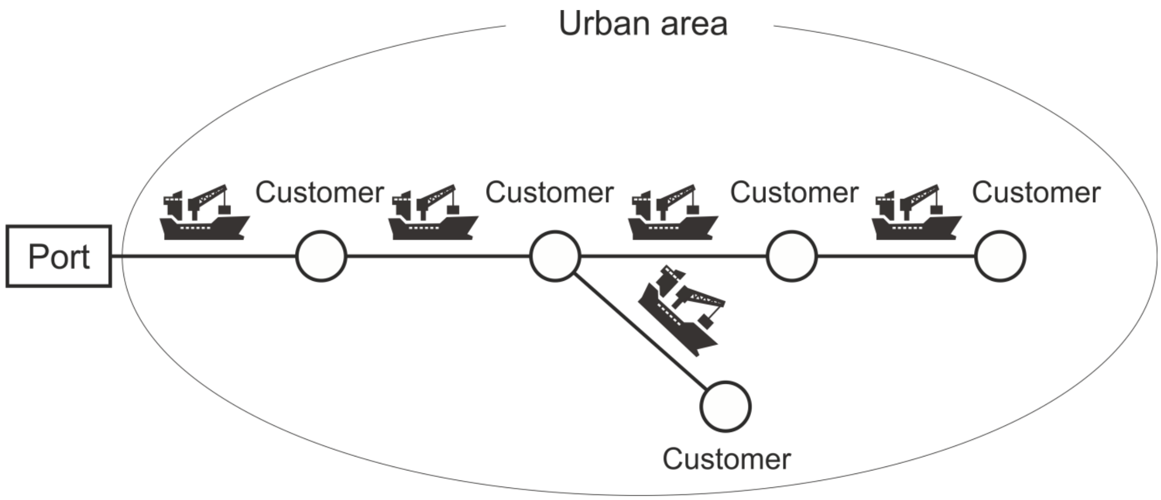

Figure 1: Model with direct customer service

Models which use another mode of transport to end customers

In this system, the vessel starts from the port (distribution or logistic center) located on city borders or in near vicinity of the city and serves given locations (nodes) used for transshipment in town residential area. Customers are served with a different mode of transport starting at these particular nodes (Figure 2). With respect to the expected economic benefits of this system, electric powered vehicles or bicycles should be used for the road transport. The service area related to the road transport must be set for each node. In this model i. e. define the set of customers.

The big advantage of this system is a large set of potential customers, wider possibilities for the usage of the different type of shipment, possibility to choose an appropriate node and higher utilization of handling equipment.

The disadvantage is the necessity of transshipments and the required optimization of the whole system with respect to service time requests of customers.

This system can be used in within large city agglomerations with navigable waterway or with a network of canals. It is suitable for supplying (retailers, restaurants, bars), delivery of parcels and mail (mainly B2B) and waste collection. In the case of parcels and mail delivery, the vessel can be used during the navigation as a center for mail sorting.

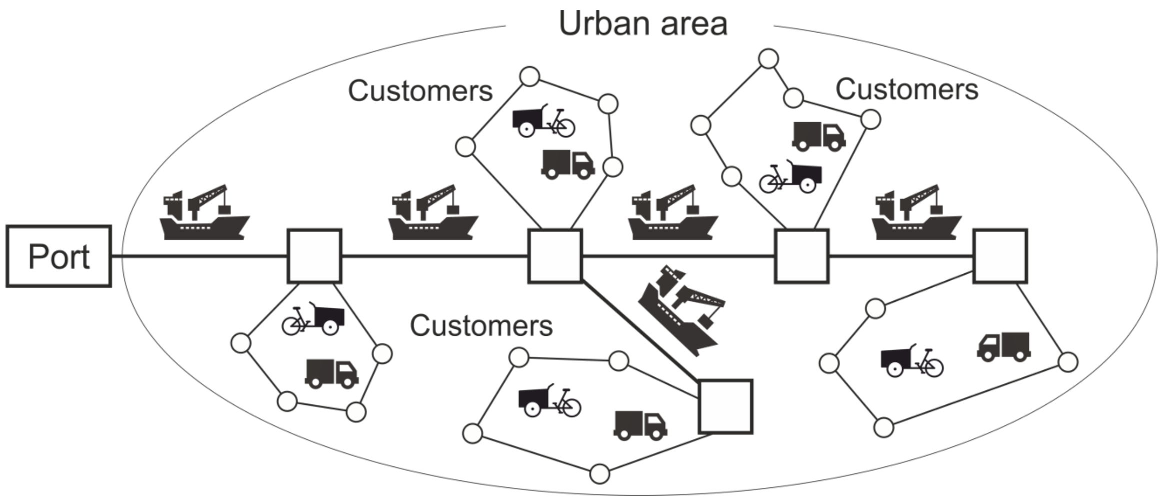

Figure 2: Model with transshipment to other transport modes

3 Proposal for a methodology for vessel choice

In consideration of specific local conditions, which have an influence on particular city logistic projects, these systems must be designed individually. Based on prerequisites from previous chapters, some principles are generalized in this chapter and are used for the proposal of a decision algorithm, which should facilitate the decision how to provide a city transport service with the use of vessels.

The choice of the appropriate transport mode can be solved as an economic model or multicriteria model [10]. In practice, the pure economic model is always used, but it has limited possibilities with respect to other points of view (e. g. technological, logistic).

The decision process of the vessel choice for city logistics has the characteristic attributes, which are typical for multicriteria analysis tasks (MCA). The decision-making subject will be in this case the present or future operator of the system. The goal is to choose the appropriate type of vessel, based on the predefined service model. (see chapter 2.2). In consideration of defined goals and a set of variants and criteria, the task can be formulated as a multicriteria option evaluation task. The procedure is determined by these steps:

Step 1: Determination of goal – the choice of appropriate vessel type.

Step 2: Definition of a set of options $X=\{X_1, X_2, \ldots, X_n\}$ – available types of vessels.

Definition of a set of criteria $Y=\{Y_1, Y_2, \ldots, Y_n\}$ – requirements on vessels.

Step 3: Partial evaluation (arrangement) of all options according to criteria.

Step 4: Combination of partial evaluations into final overall rating and the choosing the optimal solution.

This approach has the advantage that it is possible to include the weights of particular criteria. Together with this, an economic point of view can be included in the system (e. g. as a cost simulation) for individual options. The specificity of the solved decision process is the necessity to adjust options (vessels) to predefined criteria, it is, for instance, the modification of the cargo space and the equipment of vessels with handling and transshipment devices in case of older vessels or a new tailor-made vessel. For this reason, it is convenient to proceed so-called from top to bottom. Thus, first, the set of criteria is determined and second the set of options. If the criteria are divided into groups, the hierarchical structure of decision processes can be visualized as in Figure 3.

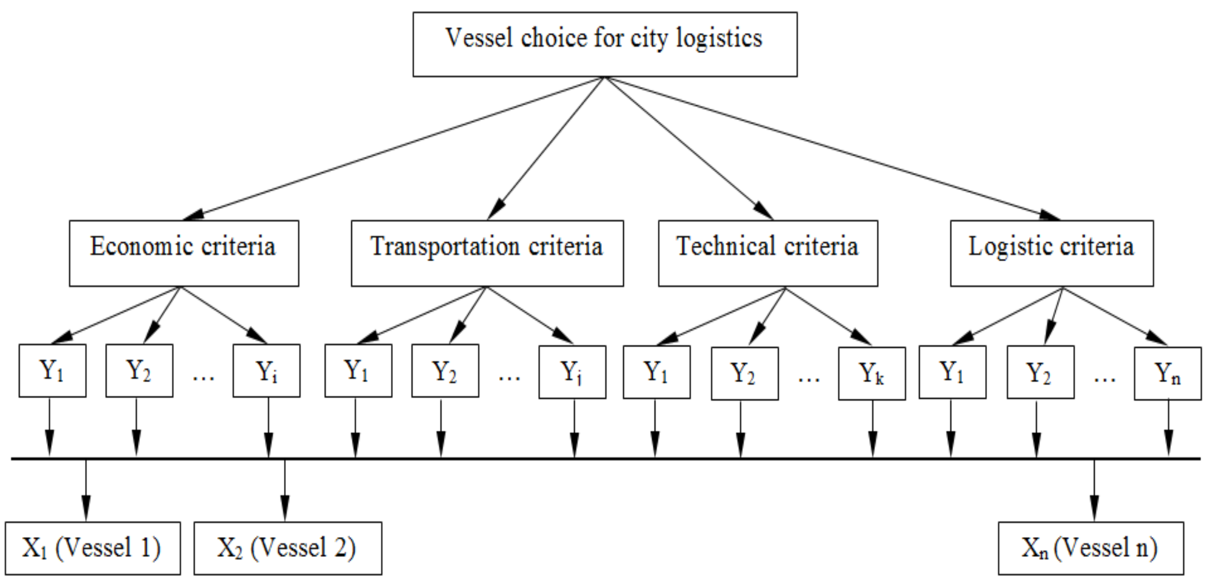

Figure 3: Hierarchical structure of the vessel choice problem

3.1 Criteria

In consideration of the very tight interconnections between waterway infrastructure and parameters of the vessel, the choosing of the suitable vessel must be solved together with its inner layout and with emphasis on handling equipment. Our solution is based on general multiple criteria models for choosing of transport modes, which take into account its transport function. The proposed methodology takes into consideration additionally the added logistic functions of the vessel (warehousing, sorting). The solution of the inner layout has to respect the specifics such as the given dimensions, the method of access to cargo compartment and the influence of vessel movement on transported goods. Also, the handling system and transshipment technology must be compatible with the equipment of riverfront areas.

Particular criteria are chosen by the decision-making subject. This subject must respect the assumed service model. In accordance with the structure in Figure 3, it is possible to define the relevant set of specific criteria within each group of criteria (table 2).

Table 2: Set of criteria to vessel choice

Group of criteria	Criterion
Economic	Input investment
	Method of vessel acquisition
	Fuel and operational material consumption
	Operational costs
	Ports and canal fees
Technical	Vessels parameters (dimensions, weight, volume)
	Reliability of vessels
	Navigation properties of vessel (stability, possibilities for maneuvers, …)
	Operational properties (conditions for operation, route)
	Propulsion
	Age and lifetime
	Possibilities for maintenance and fixing
	Fulfillment of regulations
Transportation	Structure of vessel
	Dimensions and volume of cargo compartment and specific load of cargo floor
	Layout and design of compartment for crew
	Vessel equipment for RIS applications (River Information Services).
Logistic	Purpose of vessel utilization (e. g. parcels sorting, storage in racks)
	Handling equipment
	Inner space layout
	Follow-up types of transport
	Used handling unit
	Compatibility with onshore equipment

3.2 Options

In consideration of the given requirements for city logistic systems and their very narrow specialization, it is possible to generalize the set of options, i. e. appropriate vessels for given type of system. The base condition is, that the parameters of the vessel must fit the waterway specification i. e. the maximal length, breadth and air draft are known in advance.

Group 1 – vessels for direct customer service

This specific group of vessels must be suitable mainly for the supply of restaurants (hotels) or for the waste collection (see chapter 2.2).

Characteristic factors are limited areas for transshipment handling, a small size of handling units and the onshore manual handling.

As appropriate handling units for this system, boxes, pallets, rolltainers and containers with small volume can be used.

Appropriate vessels are equipped with a crane, or the vessels are adapted for handling with manual devices. In the case of using an own crane, it is possible to use entire cargo compartments for the transported goods. The cargo compartment doesn't require special adjustment and can be divided into several parts. In the case of only manual handling, it is necessary to adjust cargo compartment for level access. The main floor with level loading with the use of ramps is convenient for cargo storage. If parcel sorting is not done on the vessel, it is necessary to arrange parcels according to customers requirements and in consideration of vessel properties directly in the loading area.

Group 2 - vessels for retailer supply or for waste collection

This group must be usable in combination with cargo road transport of the appropriate type. This type of supply is good for food with low turnover and also for nonfood products (clothing, office supplies, toys, and souvenirs). In the case of waste collection, the vessels can be used for the waste in containers and for separated waste (glass, plastics, paper and metal).

Characteristic factors are the bigger size of particular parcels, good possibility to use unified handling units and higher requirements on transshipment areas equipment (size, allowed load, handling devices). As handling units, pallets and containers can be used.

Vessels with a crane or the universal vessels for transshipment with riverfront handling systems are suitable. The cargo compartment can be used for cargo storage in its all volume. In the case of transport unified containers only, the cargo compartment can be adjusted for this purpose (e. g. fixing elements).

Group 3 - vessels for parcels distribution

This group of vessels must be usable in combination with appropriate follow-up road transport (bicycles, electro bicycles, and electro mobiles).

The characteristic factors for this group are the higher number of small parcels for different receivers, the possibility to sort parcels directly on the vessel and low requirements on transshipment areas.

The suitable vessels are vessels with cargo compartments adjusted for manual handling. The cargo department should be accessible from the riverfront level. All parcels can be sorted and grouped according to final destinations before loading or the parcels are sorted on the vessel during the navigation. In the case of onboard sorting, it is necessary to place the racks into the cargo compartment and reserve the place for sorting. The specifics of such type of cargo compartment layout in comparison to the warehouses or sorting centers in buildings are:

- small and narrow loading area (approximately 100 – 500 m^2 width 5 – 10 m),
- the necessity to design layout of racks and aisles symmetrical in consideration of vessel stability,
- the necessity of additional fixing elements of racks and parcels due to vessel movement.

3.3 Diagram of vessel choice process

The diagram of vessel choice process is shown in figure 4.

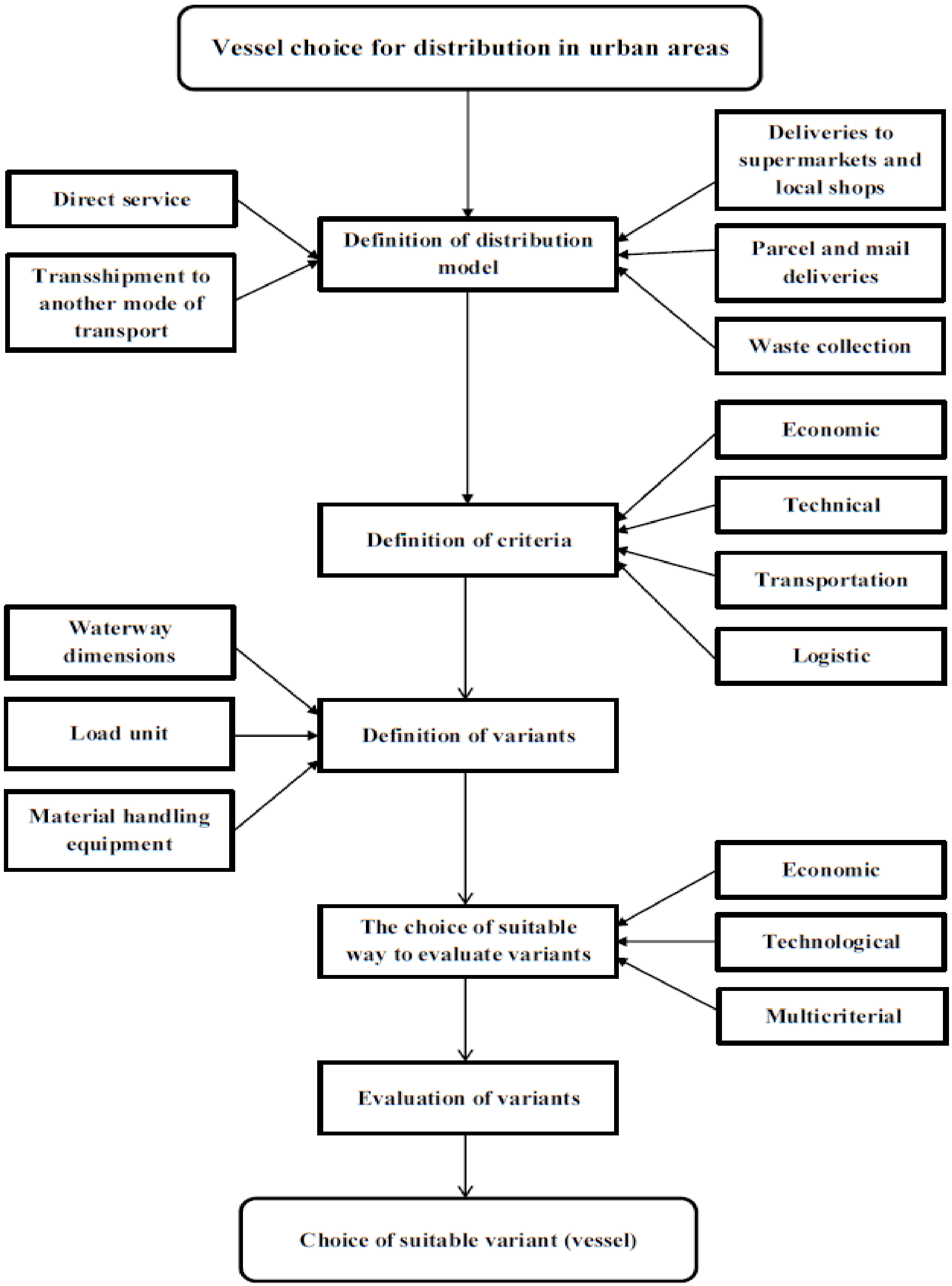

Figure 4: Vessel choice process

4 Conclusion and future work

In this paper, the parameters, which have an influence on the choice of a vessel for city logistic systems, were generalized. The generalization was based on analysis of practical experiences with the integration of vessels into the distribution chains in city agglomerations. The theoretic proposal of the decision process of vessel choice is based on above mentioned principles and on multicriteria evaluation.

The proposed methodology which is used as an initial basis for the proposal of a model for city service using water transport. The model focuses on the optimization of a necessary number of loading/unloading areas for goods distributions and on the assignment of the service area to these places. According to follow-up transport, the optimization of distribution routes will be possible for each service area.

The inland waterways are not used in city logistic in the Czech Republic today. The necessary conditions for implementation of water transport into the city logistic (year-round navigable waterway, large city agglomeration) can be met in the case of Prague (capital city of Czech republic). Only a few companies are using inland waterways for their own needs in the Prague agglomeration (e.g. supplying with building materials). In Prague agglomeration, the verification of our theoretic model will be realized with the assistance of GIS.

References:

[1] *BESTFACT. Best Practice Factory for Freight Transport*. [online] [cit. 22.1.2016] Dostupné z http://www.bestfact.net/best-practices/cl1_urbanfreight/

[2] Caris, A., S. Limbourg, C. Macharis, T. van Lier, M. Cools. "Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges." In *Journal of Transport Geography*, Vol. 41, December 2014, 126-136. Elsevier.

[3] Diziain, D., E. Taniguchi, and L. Dablanc. 2014. "Urban Logistics by Rail and Waterways in France and Japan". In *8th International Conference on City Logistics*, Vol.125 of *Procedia – Social and Behavioral Sciences,* edited by Eiichi Taniguchi and Russell G. Thompson. Bali, Indonesia, 17-19 June 2014, 159-170. Elsevier.

[4] Eisler, J. *Modelování rozhodovacích problémů v dopravě*. České vysoké učení technické v Praze, Praha, 1995.

[5] Jacyna, M., E. Szczepanski. "Holistic approach to the ecological cargo distribution in urban areas with the use of multi-modal transport. ". In *Urban Transport XIX,* Vol. 130.

of *WIT Transactions on The Built Environment,* edited by C.A. Brebbia, 2013. Wessex Institute of Technology, UK. 53-65. WIT Press.

[6] Janjevic, M. and A.B. Nidiaye. 2014. "Inland waterways transport for city logistics: a review of experiences and the role of local public authorities". In *Urban Transport XX,* Vol. 138. of *WIT Transactions on The Built Environment,* edited by C.A. Brebbia. Wessex Institute of Technology, UK. 279-290. WIT Press.

[7] Krampe, H.; Lucke, H.-J. aj. *Grundlagen der Logistik. Einführung in Theorie und Praxis logistischer Systeme*. 4. überarb. und erw. Aufl. München: Hussverlag, 2012. ISBN 978-3-941-418-80-6.

[8] Ledvinová, M. "City logistika a navrhování dopravních systémů měst." In *Perner's Contacts*, Vol. 3, Nr. 5, December 2008, 196-202. Univerzita Pardubice, Dopravní fakulta Jana Pernera.

[9] Ledvinová, M. *Model obnovy silničních nákladních vozidel*. Dissertation. Pardubice: Univerzita Pardubice, 2004.

[10] Maes, J., C. Sys and T. Vanelslander "City Logistics by Water: Good Practices and Scope for Expansion". In *Transport of Water versus Transport over Water: Exploring the Dynamic Interplay of Transport and Water.* Vol. 58 of Operations Research/Computer Science Interfaces Series, edited by C. Ocampo-Martinez and R.R. Negenborn, 2015. Springer International Publishing, 413-438.

[11] Trojanowski, J. and S. Iwan. "Analysis of Szczecin waterways in terms of their use to handle freight transport in urban areas". In *1st International Conference Green Cities 2014 – Green Logistics for Greener Cities*, Vol. 151 of *Procedia – Social and Behavioral Sciences*, edited by Stanisław Iwan and Russell G. Thompson. Szczecin, Poland, 19-21 May 2014, 331-341. Elsevier.

[12] Vert chez Vous stoppe l'exploitation de sa navette fluviale à Paris. [online] 3 September 2014. *Le portail Transport et Logistique*: http://www.wk-transport-logistique.fr.