Interreg
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METRO

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WP 3 / Activity 3.2

An Analysis of Basic Parameters of Double-Ended Ferries as Basis for a New Hybrid Ferry Design

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Summary

1. INTRODUCTION

The process of ship design combines wide range of disciplines and analysis methods, and by no doubts it should be methodically approached. The ship design may be considered as being composed of four main phases: a concept design, a preliminary design, a contractual design, and detailed design [1]. The first two phases are also known as basic design.

One of the usual steps when the preliminary ship design is elaborated is data gathering of built similar ships. Data to be gathered may include a ship type, size, deadweight, speed, main engine power, etc. These data are available in various publications or databases. Until present days, a lot of databases were made in which ship's basic parameters were gathered and analyzed. These studies were mostly made for cargo ships, i.e. containerships, bulk carriers, tankers, general cargo ships [1, 2, 3, 4] and very rare relate on double-ended ferries, if at all.

One of the goals of the project METRO (Maritime Environment-friendly TRanspOrt systems) is the development of new hybrid double-ended ferry that is assumed to operate in the Northern Adriatic Sea. For the purposes of the EU Interreg project METRO (Maritime Environment-friendly TRanspOrt systems) it is necessary to estimate a double-ended ferry that is assumed to operate in Northern Adriatic Sea. The main idea is the implementation of hybrid technologies to get more environmentally sustainable ships. The double-ended ferry is intended for short routes between Croatian coast and islands.

In order to get a broader picture of the basic parameters of these types of ferries, the formation of extensive database was undertaken. The established databases will serve as guidelines for the design of a double-ended ferry.

2. DATABASE FORMATION

To form a database, the data were mainly gathered from three databases [5, 6, 7], but also some other websites that are focused on ferries and ferry transport were used [8, 9]. The available data for ferries were mainly related to basic parameters such as the length overall (L_{OA}), breadth (B), draft (T), power of the main engine(s) (P), service (or average) speed (V), gross tonnage (GT) and deadweight (DW).

Many of the data required additional verification. For example, the speed was usually referred to as speed in service but for some specific ferries it was taken from [7] as an average speed. Since the passenger and vehicle capacities are of particular importance for the ferries, these data were also gathered and analyzed.

In addition to these basic parameters, some other useful data were additionally gathered. These additional data include route lengths, ferry lane meters, number of passenger and cargo decks, whether a ferry has a bow thruster or does it has an ice class. However, because these data were not available for all ferries, they were not analyzed and presented in this study. Some of the other parameters, such as depth or freeboard were not specified for some ferries so it was also decided not to include these data in the databases. The vehicle capacity is often defined as the length of lanes but it was not possible to validate available figures so these data were also discarded as unreliable.

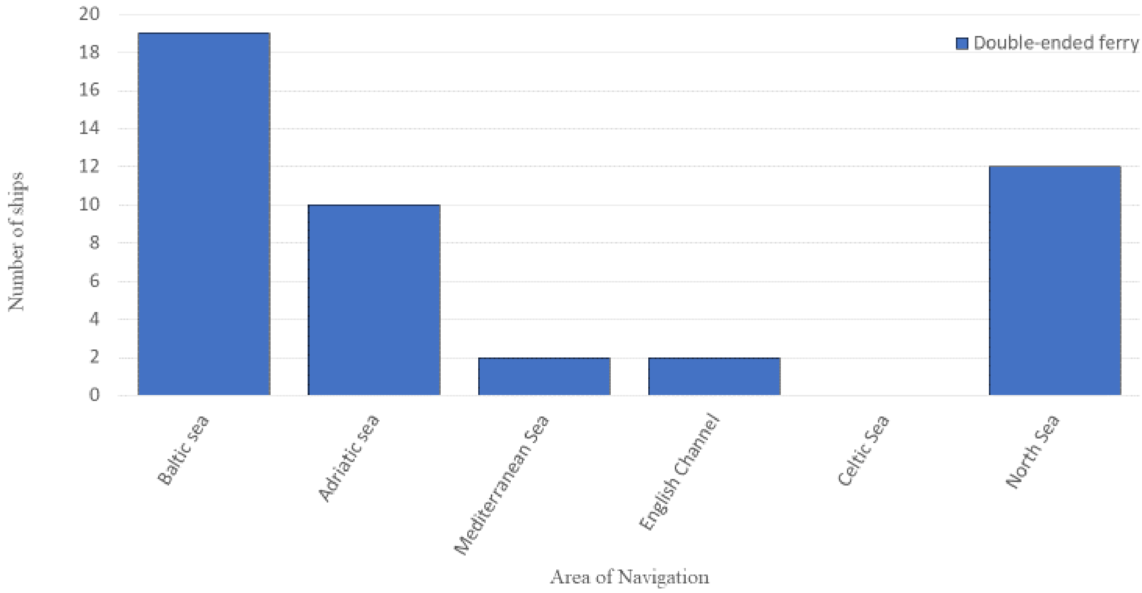

Figure 1. Number of ferries and the area of navigation

Data were gathered for ferries that operate in the European seas. Scandinavian and Baltic countries are all connected via ferry lines and sea traffic network there is highly branched, hence major part of data consists of ferries from that area. Other navigation areas where ferries listed in the database operate include Mediterranean Sea, English Channel and Adriatic Sea, Figure 1. No ferries were found for the Celtic sea.

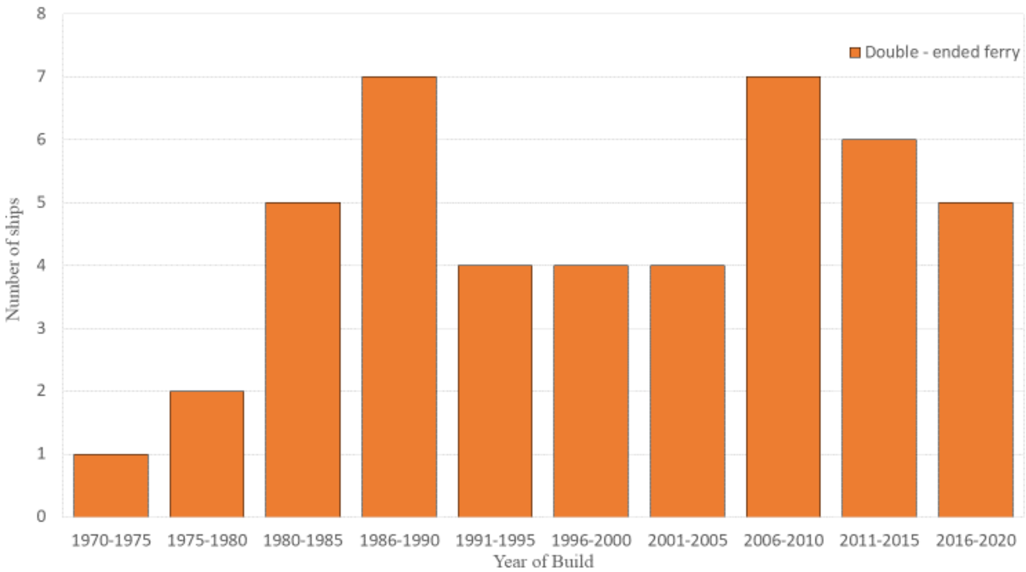

Figure 2. Number of ferries and built year

While creating the database of double-ended ferries, the L_{OA} criterion was not taken into account since the L_{OA} of the existing double-ended ferries matches perfectly for the double-ended ferries that can operate in the area of the Northern Adriatic. When forming this database, only the built year was taken into account. Since the number of available ferries was smaller, all ferries built between 1970 and 2019 for which data were available were included in the database, Figure 2.

Finally, only monohull ferries were included in the database since it was concluded that multihulls with the speed of over 30 knots were not of interest for the project. It was also important to sort out all the sisterships and exclude them from the databases in order to get reliable results. The database contains 45 double-ended ferries, for which the parameters were gathered in the second half of 2019.

3. DATA ANALYSIS

In this section, the results of the analysis of following basic parameters are presented: L_{OA} (m), *B* (m), *T* (m), *P* (kW), *V* (kn), *GT*, *DW* (t) and passenger and car capacity.

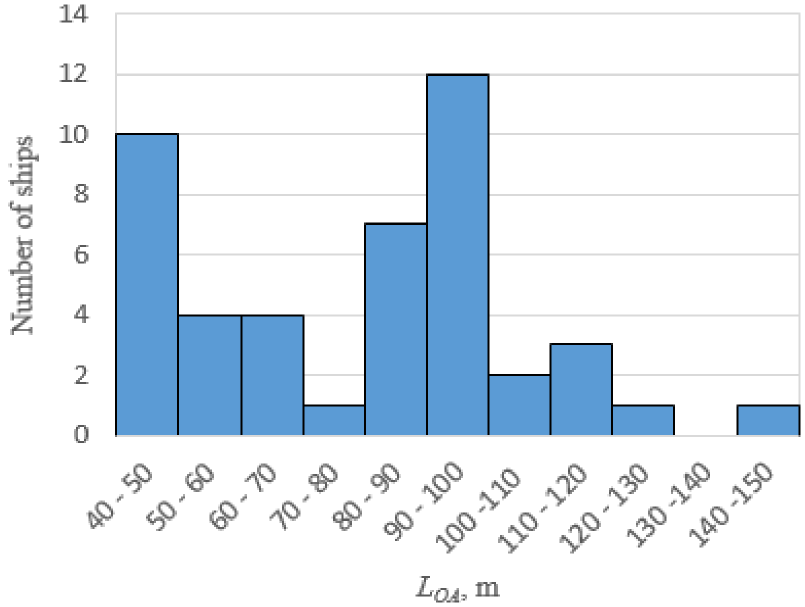

Figure 3. L_{OA} and number of double-ended ferries

Figure 3. shows the number of double-ended ferries based on their L_{OA}, which ranges from 40 to 150 meters. Most ferries (84%) have L_{OA} in the range between 40 and 100 m. Short routes on which double-ended ferries usually operate do not demand larger L_{OA} and for this kind of routes it is important to sail frequently and not waste time in ports. Therefore, the need for adequate capacity is offset by a shorter port maneuvering, berthing and loading/unloading. Due to these requirements, a double-ended ferry has the specific symmetric hull form and propulsion system, allowing an equally efficient sailing ahead and astern.

Figures 4. and 5. show the number of ferries as a function of *B* and *T*. *B* of most ferries (82%) ranges from 12 to 20 m, with an average value of 15.9 m. *B* rarely exceeds 20 m. *T* mostly ranges from 2 to 5 meters (95%), with an average value of 3.4 m.

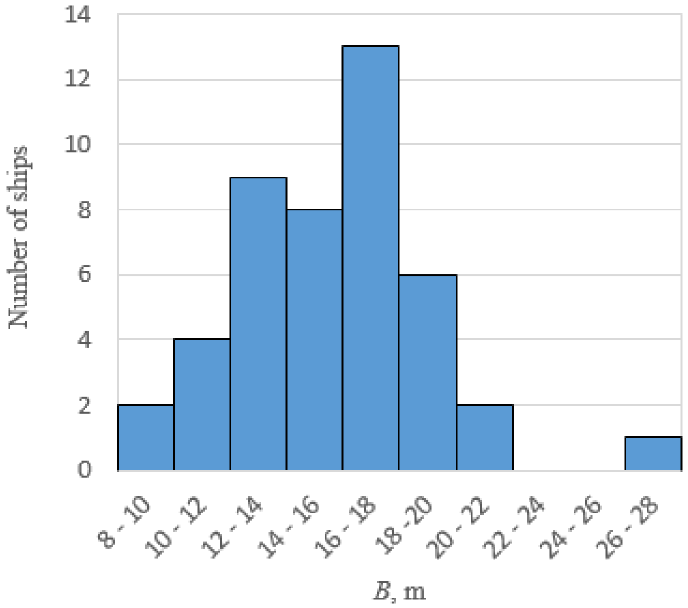

Figure 4. *B* and number of double ended ferries

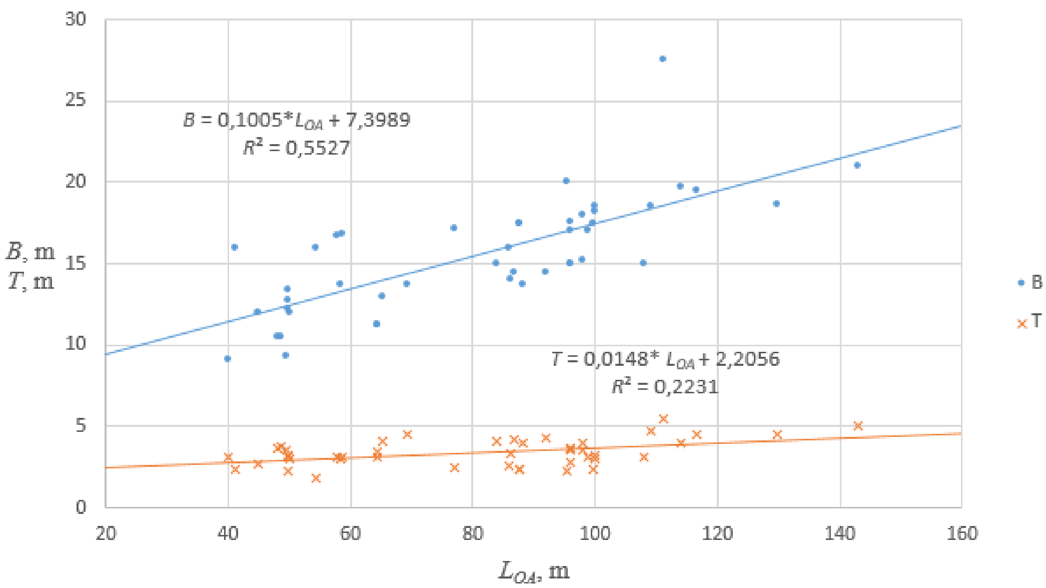

Figure 5. *B* and *T* as a function of L_{OA}

Scatter plots in Figure 5. show that L_{OA} strongly influences the B and T, and both B and T proportionally follow the increase in L_{OA}. The change of B can be represented with the formula:

$$B = 0.1005\ L_{OA} + 7.3989. \tag{1}$$

The value of the R^2 coefficient is 0.5527. For double-ended ferries, L_{OA}/B ratio ranges from 4.4 to 6.8, with an average value of 5.18 m. A slight increase of L_{OA}/B ratio was observed over the years also for these ferries, with an average value of 5 for ferries built between 1970 and 2000, and 5.4 for those built between 2000 and 2019. The values of these ratios are lower comparing with for example ratios of Ro-Pax ferries because double-ended ferries are shorter and larger capacities are obtained by the beamier hull form.

The dependence of T on L_{OA} is shown in Figure 5. and the change of T can be represented with the formula:

$$T = 0.0148\ L_{OA} + 2.2056. \tag{2}$$

The value of the R^2 coefficient is 0.2231.

Beamier hulls of double-ended ferries also cause an increase in the B/T ratio. This ratio has also increased over the years, from an average value of 4.2 for ferries built from 1970 to 2000, up to the average value of 5.4, for ferries built from 2000 until 2019. The overall average value of B/T ratio is 4.8.

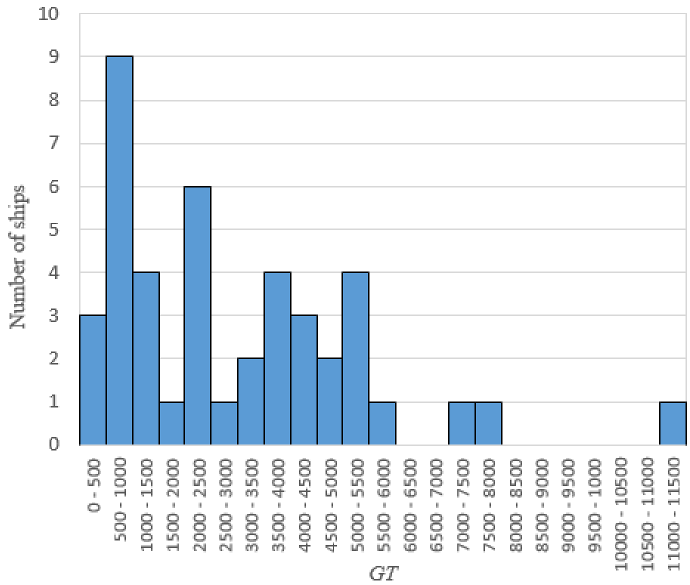

Figure 6. *GT* and number of double ended ferries

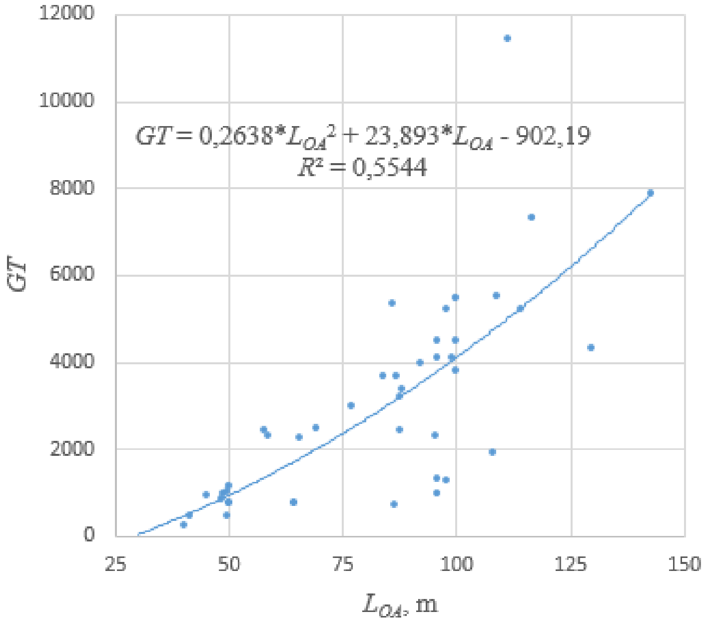

Figure 7. *GT* as a function of L_{OA}

Figure 6. shows that significant part of double-ended ferries has *GT* in range from 0 to 5500, with only three cases above 7000. Figure 7. shows *GT* as a function of L_{OA}, and it can be noticed that one ferry significantly deviates from that range with the value of 11434. This value can be explained with the high passenger capacity (1250) and car capacity (240) which can be noticed in Figure 11. and 12.

The deadweight for most of the double-ended ferries (91%) is within 1400 t, as is shown in Figure 5. The deadweight can be roughly estimated from the formula, Figure 9:

$$DW = 0.0532 \cdot L_{OA}^2 + 5.2602 \cdot L_{OA} \tag{3}$$

The value of the R^2 coefficient is 0.2699.

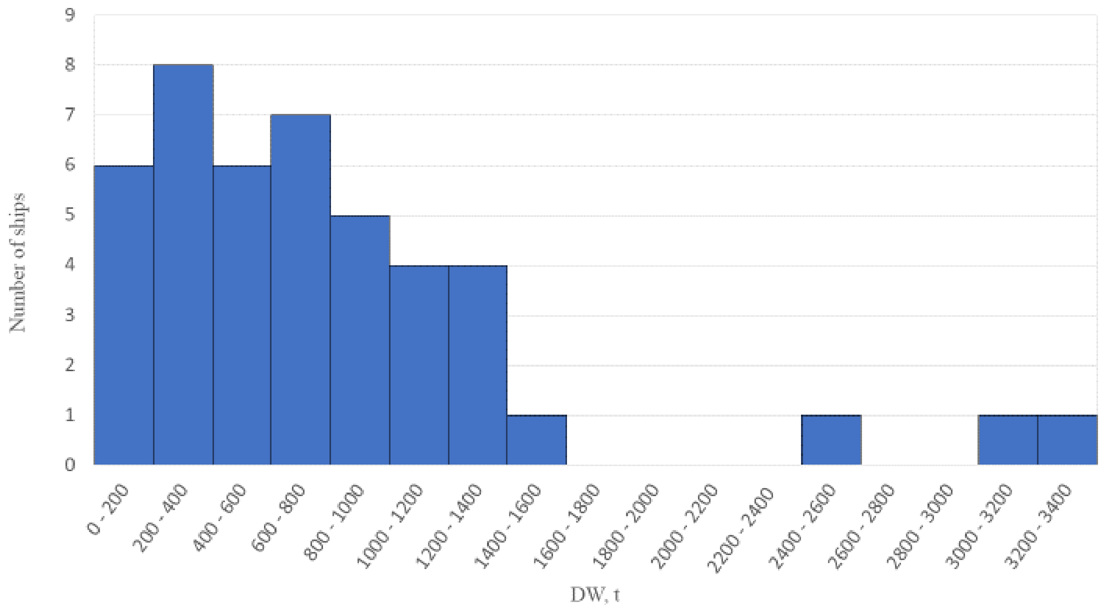

Figure 8. *DW* and number of double ended ferries

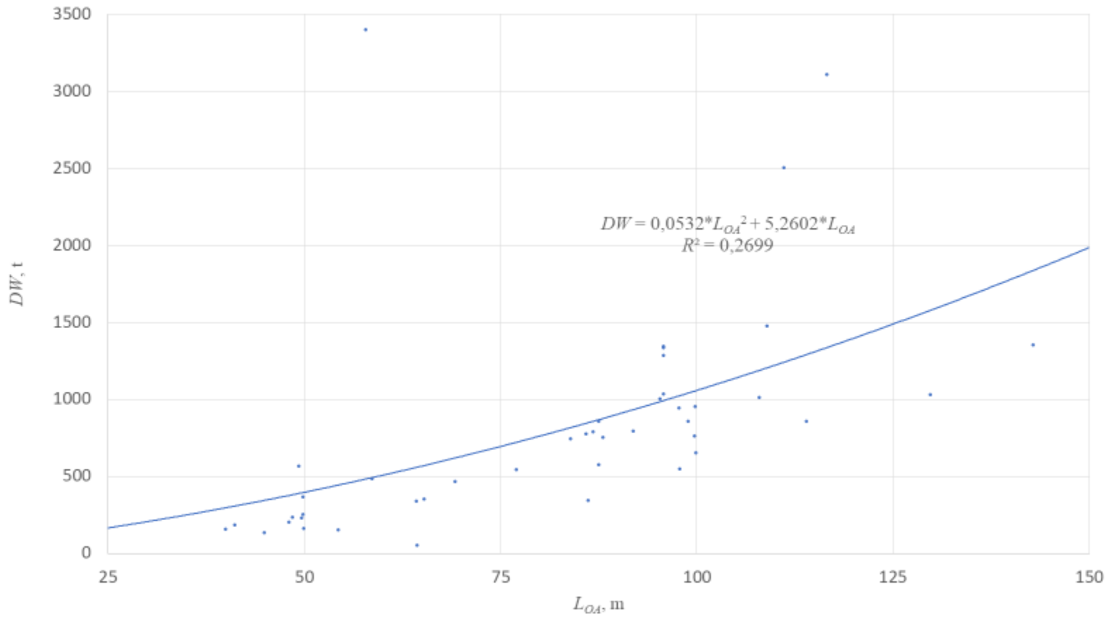

Figure 9. *DW* as a function of L_{OA}

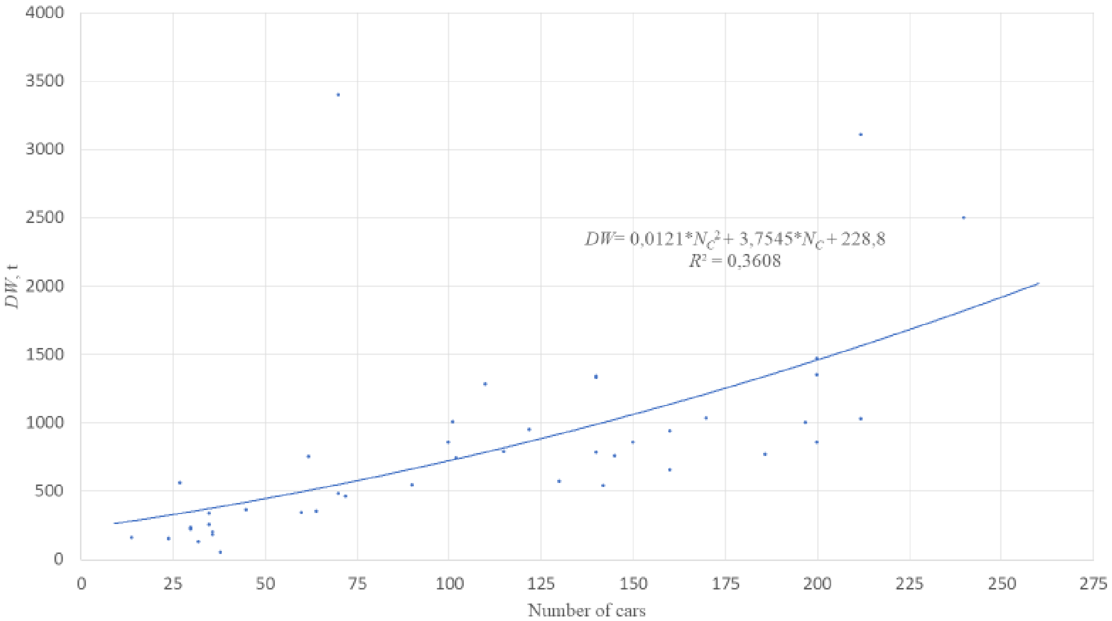

Figure 10. *DW* as a function of number of cars

The three double-ended ferries differ significantly from the group of others which were analyzed. Two of them with *DW* over 2400 t have large car capacities, more than 220 cars, and one of them has the highest *DW* (3397 t) with a very small car capacity (70). For the rest of the analyzed ferries, as shown in Figure 24., *dwt* and the car capacity are linked over the following formula:

$$DW = 0.0121 \cdot N_C^2 + 3.7545 \cdot N_C + 228.8. \tag{4}$$

The value of the R^2 coefficient is 0.3608.

Most of double-ended ferries sail on short, local routes so their passenger and car capacities are determined by route needs and port capacities. Number of passenger decks varies from ferry to ferry, and within the database the ferries have from one to three passenger decks. The passenger capacity depends of number of decks and because of this the correlation between the number of passengers and L_{OA} is lower, with higher dispersion of data, shown in Figure 11. Passenger capacities range from 86 to 1250 with an average value of 464. The number of passengers can be estimated using the formula:

$$N_P = 6.3359 \cdot L_{OA}^2 - 49.38. \tag{5}$$

The value of the R^2 coefficient is 0.3873.

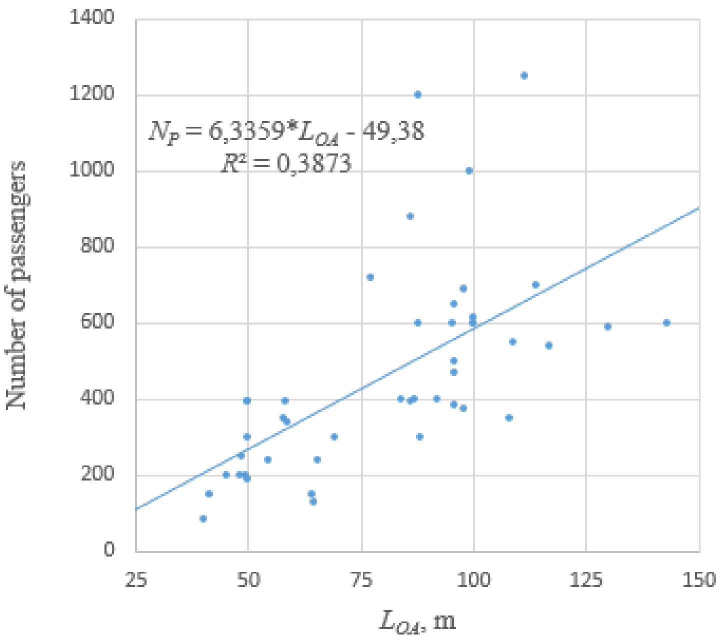

Figure 11. Number of passengers as a function of L_{OA}

The car capacity mostly depends on the area of decks where cars or other vehicles are parked. These ferries rarely have more than one deck intended for cars and in this manner car capacity is strongly correlated with L_{OA} and B, as is shown in Figure 12. Car capacities range from 14 to 240 vehicles, with an average value of 104 cars. The number of cars can be estimated using the formula:

$$N_C = 2.2216 \cdot L_{OA} - 75.432. \quad (6)$$

The value of the R^2 coefficient is 0.7615.

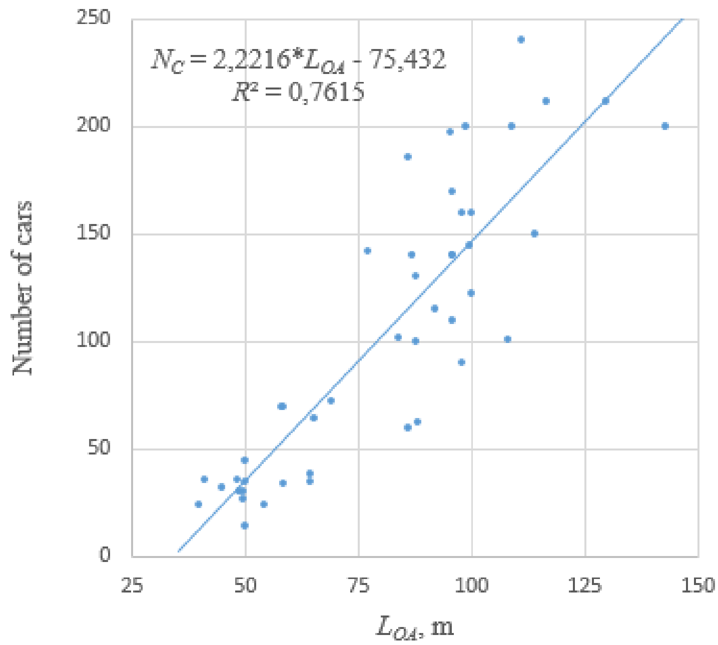

Figure 12. Number of cars as a function of L_{OA}

Figure 13. shows that *P* is considerably correlated with L_{OA}, and ranges from 700 to 6000 kW. For one hybrid ferry *P* reaches 7500 kW and the reason for this is that diesel engine power (3350 kW) and electric batteries power (4150 kW) were summed. The average *P* is 2608.5 kW. *P* can be estimated using the formula:

$$P = 0.2459 \cdot L_{OA}^2 + 2{,}1519\ L_{OA} + 714{,}33. \quad (7)$$

The value of the R^2 coefficient is 0.415.

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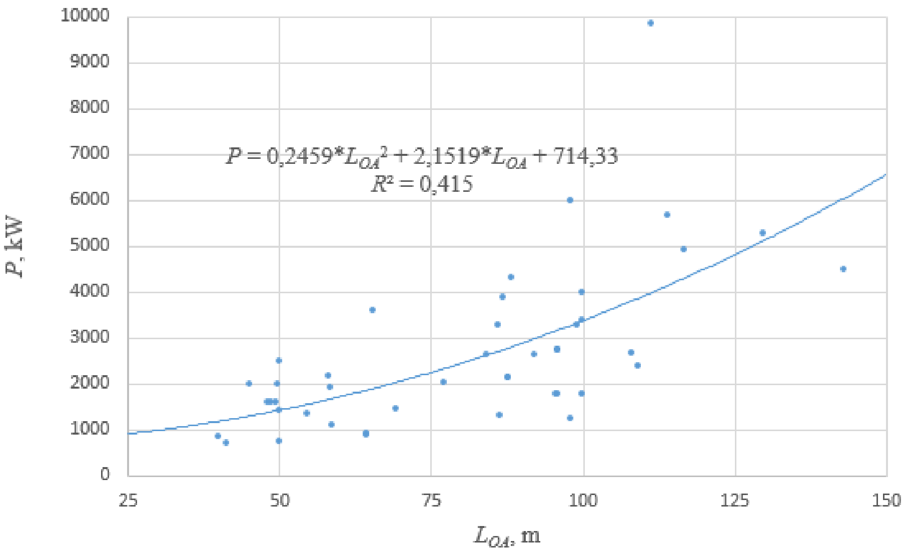

Figure 13. P as a function of L_{OA}

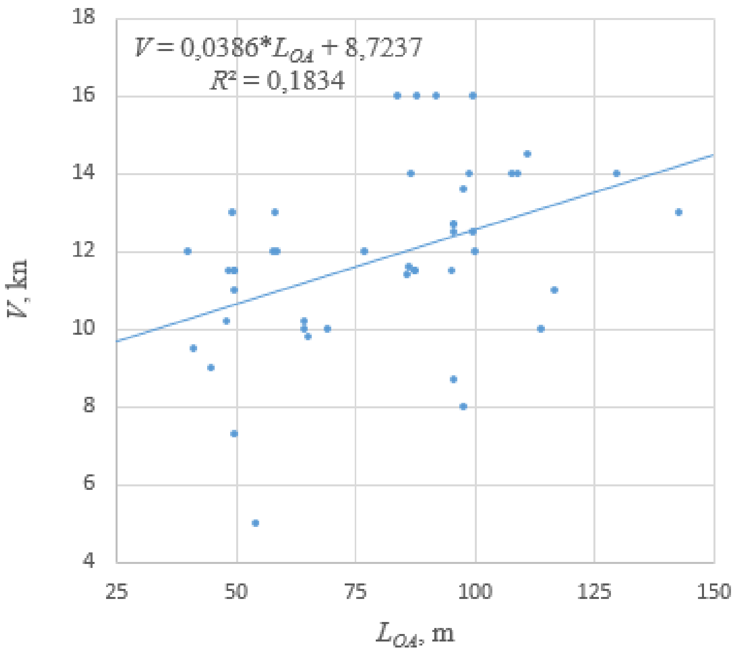

Figure 14. V as a function of L_{OA}

In Figure 14. it can be seen that there is a weak correlation between V and L_{OA}. V highly depends on service conditions, route lengths and passengers and vehicles transport needs. V of double-ended ferries range from 5 to 16 knots, with an average value of 11.8 knots. *V* can be estimated using the formula:

$$V = 0.0386 \cdot L_{OA} + 8.7237. \qquad (8)$$

The value of the R^2 coefficient is 0.1834.

4. GUIDELINES FOR THE CONCEPT DESIGN OF A HYBRID FERRY

Results obtained from the analysis of established database were used for the estimation of basic parameters of hybrid double-ended ferry which was destined to be developed within the project METRO.

Table 1. Double-ended ferry – route Brestova-Porozina

Double-ended ferry						
Main particulars	**M/V Bol**	**M/V Brestova**	**New design**			
L_{OA}, m	95.4	58,17	60.0	70.0	80.0	90.0
B, m	20.0	16,8	13.423	14,434	15,439	16.444
T, m	2.30	2,70	3.094	3.242	3.390	3.538
GT	2330	2315	1481	2063	2698	3385
DW, t	1000	482	507.1	628.9	761.3	904.3
IMO number	8736344	8625090	-	-	-	-
Build year	2006	1985	-	-	-	-
Passenger capacity	600	338	331 *	394 *	457 *	521 *
Car capacity	176	70	58 *	80 *	102 *	125 *
P, kW	1412	2200	1728.7	2069.9	2460.2	2899.8
V, kn	12	12	11.04	11.42	11.81	12.19

* - To be taken with caution.

This ferry is intended to operate on a route that was taken as relevant for the project METRO [10]. The route, with the length of 2,7 nautical miles, should connect Istrian peninsula with the Island of Cres via local ports in Brestova and Porozina. Basic parameters for the new hybrid ferry were determined using the formulas and diagrams presented in this study, and are shown in Table 1. As the exact basic parameters of the new ferry are still unknown at this very early stage of the preliminary design, the basic parameters were estimated for four different ferry lengths, which fall within the expected range of ferry lengths. In the table the basic parameters of existing ferries that sail on these routes are also shown. The estimated basic parameters are in good agreement with the basic parameters of the existing ferries. It can be pointed out that the existing ferries are not specifically optimized for the indicated routes.

5. CONCLUSION

One of the main goals of the METRO project is the development of new hybrid double-ended ferry, which may be suitable for the transportation of passengers and vehicles between ports in the Northern Adriatic. In order to obtain guidelines for the selection of basic parameters of new ferry, an appropriate database was formed.

The following data were gathered as basic parameters: length overall, breadth, draft, main engine power, speed, gross tonnage, deadweight as well as passenger and car capacity. In addition to these data, the database partly contains some other data (for example route lengths, ferry lane meters, number of passenger and cargo decks, etc.), but these data were not analyzed due to their incompleteness or unreliability.

Given that a quite sufficient number of ferries were gathered, the database provides very good guidelines for a new hybrid ferry design. Based on the data analyzed and formulas developed within the study, the basic parameters of four ferries within the range of lengths that could fit well into the Northern Adriatic area were preliminary selected. The selection of these basic parameters represents the first step in the process of development of new hybrid double-ended ferry within the project METRO.

NOMENCLATURE

B - breadth, m

DW - deadweight, t

GT - gross tonnage

L_{OA} - length over all, m

N_C - car capacity

N_P - passenger capacity

P - total power of the main engines, kW

T - draft, m

V - speed, kn

REFERENCES

[1] Papanikolau, A. (2014), *Ship design - Methodologies of Preliminary Design.* Springer Netherlands, Dordrecht.

[2] Lamb, T. (1969), *A Ship Design Procedure*, Marine Technology, Volume 6, Issue 4, pp 362-405.

[3] Watson, D. G. M. (1998), *Practical Ship Design*, Elsevier Ocean Engineering Book Series, Volume I

[4] Schneekluth, H., Bertram V. (1998), *Ship Design for Efficiency and Economy*, Butterworth–Heinemann, Oxford

[5] …, Ship database, Available from: www.matkustajalaivat.com [accessed August – October 2019]

[6] …, Ship database, Available from: www.ferry-site.dk [accessed August – October 2019]

[7] …, MarineTraffic, Available from: www.marinetraffic.com [accessed August – October 2019]

[8] …, Local line Ferries, Available from: https://www.jadrolinija.hr/en/about-us/ships/ferries/local-line-ferries [accessed August – October 2019]

[9] …, Ferries for International Lines, Available from: https://www.jadrolinija.hr/en/about-us/ships/ferries/ferries-for-coastal-and-international-shipping (accessed August – October 2019)

[10] …, (2019) *Identification of Research Area, Referent Lines and Referent Ships.* Faculty of Maritime Studies, University of Rijeka, Internal report – project METRO (Maritime Environment-friendly TRanspOrt systems) funded by the 2014-2020 Interreg V-A Italy - Croatia CBC Programme.