WP 3 / Activity 3.2

An Analysis of Basic Parameters of Ro-Pax 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 only few were focused on Ro-Pax ferries [5].

One of the goals of the project METRO (Maritime Environment-friendly TRanspOrt systems) is the development of new hybrid Ro-Pax ferry that are 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 Ro-Pax 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 Ro-Pax ferry is intended for the Trans Adriatic routes between Croatia and Italy.

In order to get a broader picture of the basic parameters of this type of ferry, the formation of extensive databases was undertaken. The established databases will serve as guidelines for the design of hybrid Ro-Pax ferry.

2. DATABASE FORMATION

To form a database, the data were mainly gathered from three databases [6, 7, 8], but also some other websites that are focused on ferries and ferry transport were used [9, 10]. 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 [8] 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.

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, Adriatic Sea and Celtic Sea, Figure 1.

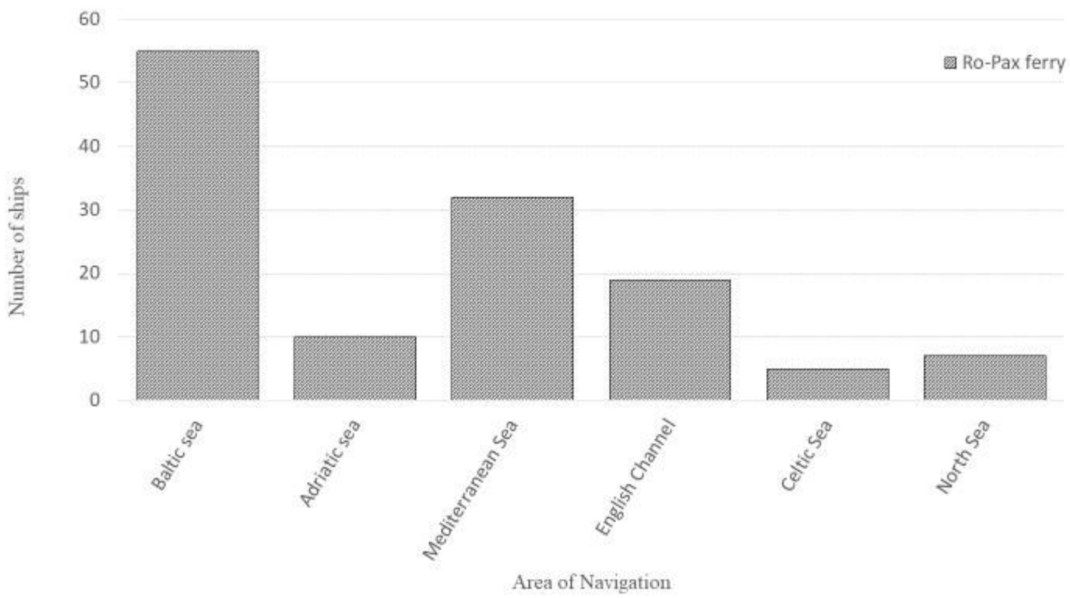

Figure 1. Number of ferries and the area of navigation

While creating the database of Ro-Pax ferries, two main filtering criteria were set. The first one was a built year, and only ships built after 1980 were taken into account, Figure 2. The second criterion was L_{OA} in a way that only ferries up to 200 m were included in the database. The only exceptions were three ferries slightly longer and L_{OA} of the longest goes up to 203 m. The first criterion was set because ferries have changed over the years and it was decided that parameters of older ferries would not be relevant for the databases. The second criterion was set because of the METRO project's program area which is Northern Adriatic. Ferries that operate between Italy and Croatia, particularly passenger ports Ancona and Split, are much shorter than 200 meters, with the maximum L_{OA} of 147.97 m. Therefore, ferries longer than 200 meters were not included in the database.

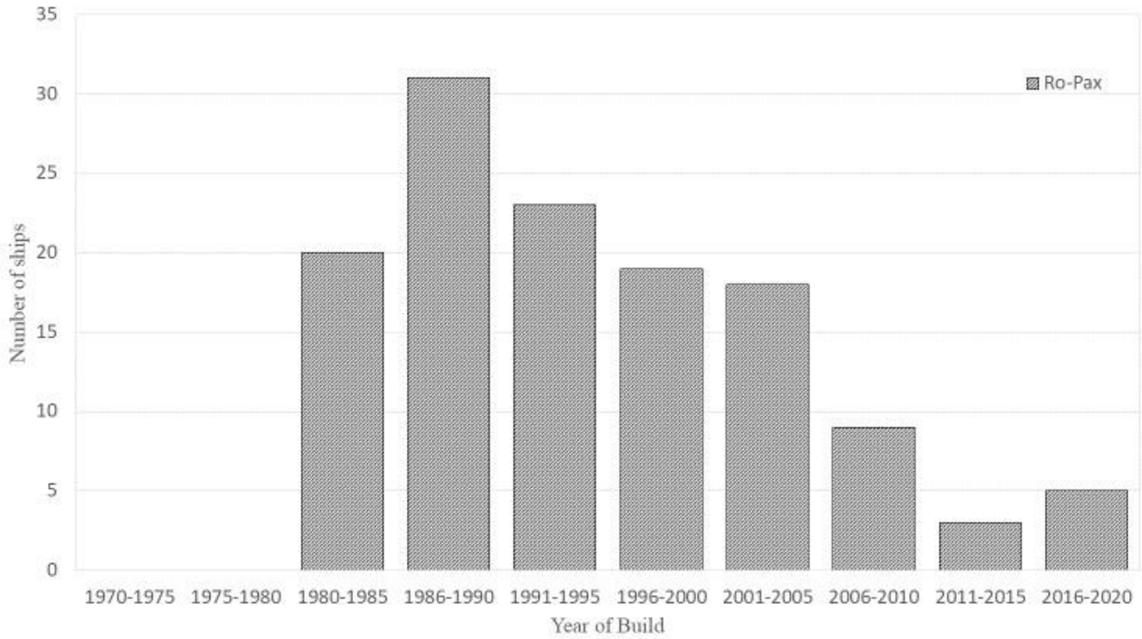

Figure 2. Number of ferries and built year

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 databases contain 128 Ro-Pax ferries, for which the parameters were gathered in the second half of 2019.

3. DATA ANALYSIS

In this chapter, 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. For a better presentation, the results for each database were shown separately. In the first part, the analysis of main parameters of Ro-Pax ferries is shown while the analysis of double-ended ferries is presented in the second part, in the same way as for Ro-Pax ferries.

The histogram in Figure 3. shows the number of ferries as a function of L_{OA}. The ferries were grouped according to their lengths within 10 m. It can be noticed that a significant part of ferries (71%) fall within the range of L_{OA} between 150 to 200 m. It can be further noticed that a major part of them (39%) are in the range of L_{OA} between 160 to 180 meters.

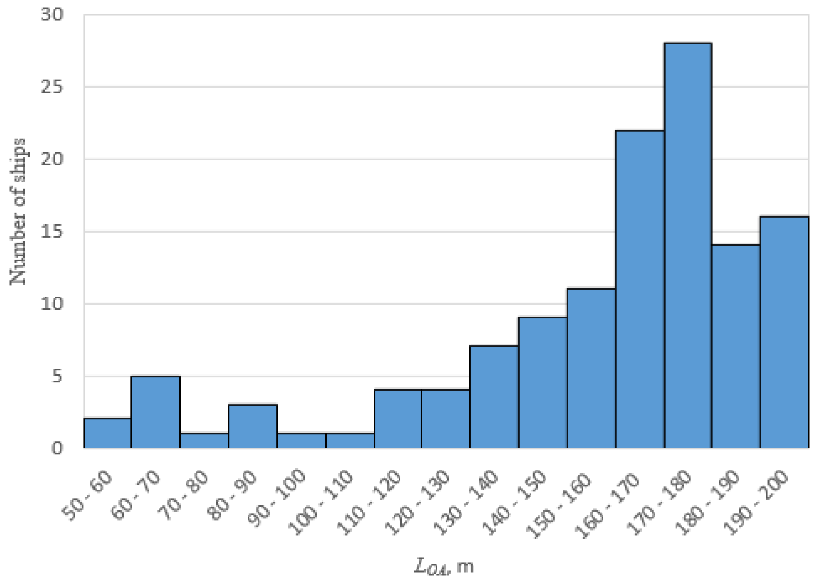

Figure 3. L_{OA} and number of Ro-Pax ferries

Figures 4. and 5. show the number of ferries as a function of *B* and *T*. The results largely follow those obtained for the L_{OA} and something like that could have been expected. *B* mostly ranges between 24 and 30 m (77.3%), with only few of them over 30 m, Figure 4. Also, most of the ferries (77.3%) have *T* between 5.5 and 7.0 m, which are the quite common values in relation to L_{OA}.

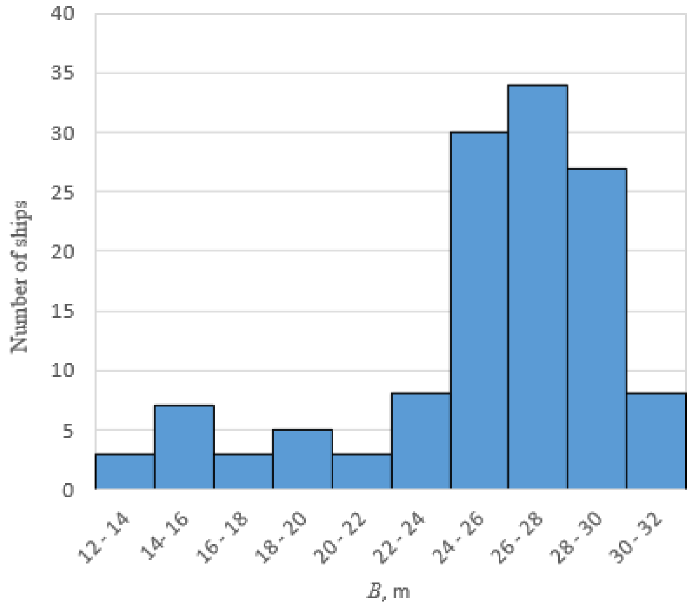

Figure 4. *B* and number of Ro-Pax ferries

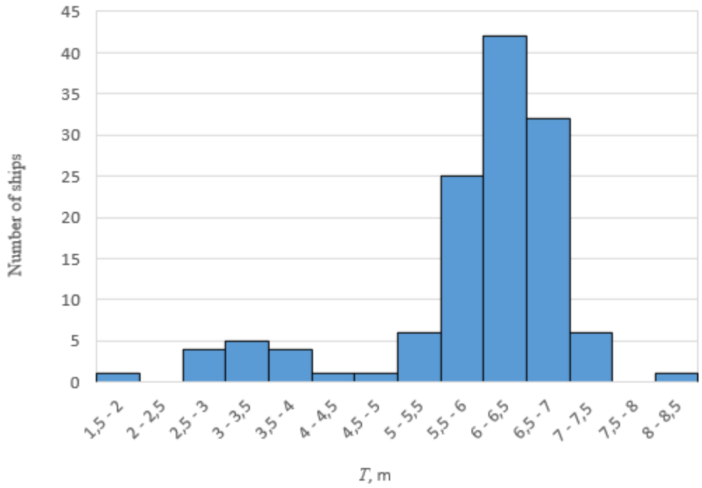

Figure 5. *T* and number of Ro-Pax ferries

The scatter plot shown on Figure 6. shows that L_{OA} affects the *B* and *T* and it can be noticed that *B* and *T* change proportionally with L_{OA}. The ferries that are circled show some discrepancies from the rest of ferries. These are older ships, having the larger *B* in relation to the L_{OA}. A linear regression was made for these data, and the change of *B* can be represented with the formula:

$$B = 0.1026 \cdot L_{OA} + 8.8904. \qquad (1)$$

The value of the R^2 coefficient is 0.6786. Ratio L_{OA}/B ranges from 3.9 to 8.2, and the mean value is 6.23. It was noticed that L_{OA}/B ratio slightly increases for new ferries. While in years from 1980 to 2000 the mean value of L_{OA}/B ratio was 6.04, the mean value of L_{OA}/B ratio for the period between 2000 and 2019 raised to 6.7.

Figure 6. also shows the dependence of *T* on the L_{OA}. A strong correlation can be observed between *T* and L_{OA}, and the change of *T* can be represented with the formula:

$$T = 0.0271 \cdot L_{OA} + 1.6105. \qquad (2)$$

The value of the R^2 coefficient is 0.7262. Ratio *B/T* ranges from 2.86 to 7.6, and the mean value is 4.32. It can be noted that there were no significant changes in this ratio over the years. In the period from 1980 to 2000, the mean value of *B/T* ratio was 4.35, while in the period from 2000 to 2019, it was 4.24. Compared to other types of ships of similar L_{OA}, Ro-Pax ferries have relatively low *T* to the fact that they carry relatively light mass cargos.

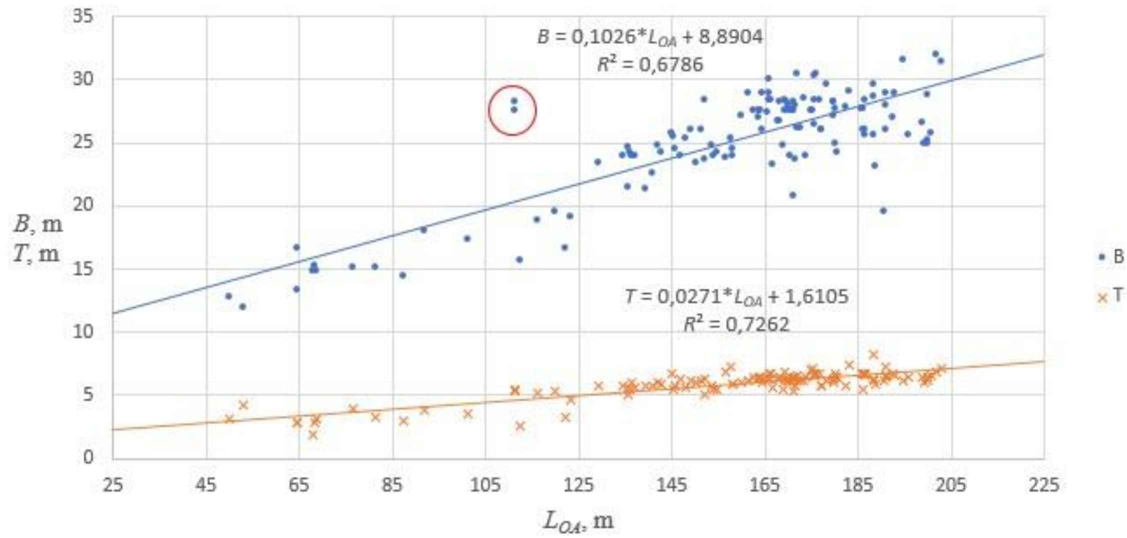

Figure 6. *B* and *T* as a function of L_{OA}

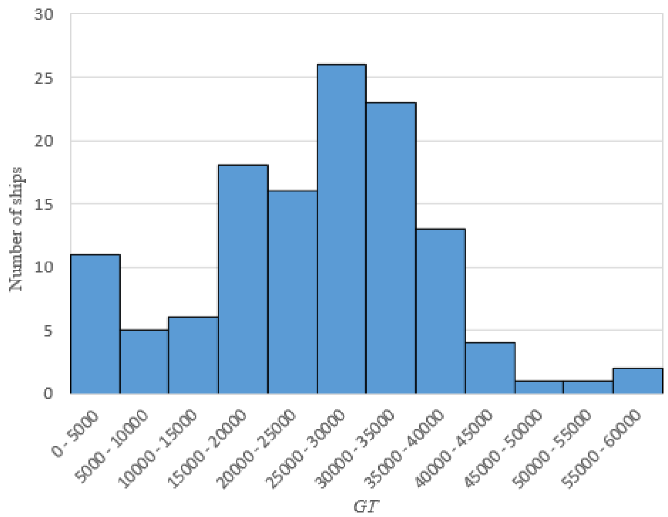

Figure 7. *GT* and number of Ro-Pax ferries

Figure 7. shows the number of ferries as a function of *GT*. The ferries were grouped according to their *GT* within value of 5000. Figure 7. shows that significant part (75.6%) of Ro-Pax ferries has *GT* ranging from 15000 to 40000, with only three ferries over 50000. A strong correlation can be observed between *GT* and L_{OA} in Figure 8., which can be represented with the formula:

$$GT = 0.8484 \cdot L_{OA}^2 + 57.358 \cdot L_{OA} - 6320.3. \quad (3)$$

The value of the R^2 coefficient is 0.7025.

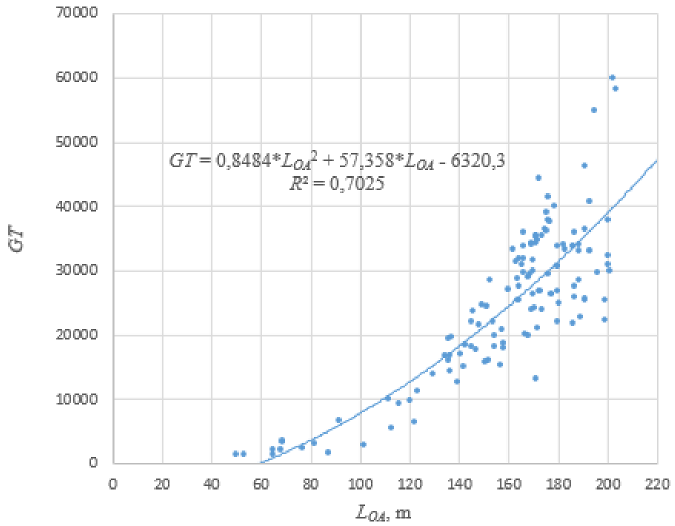

Figure 8. *GT* as a function of L_{OA}

Figure 9. shows the number of ferries as a function of *DW*. The ferries were grouped according to their *DW* within the value of 1000. For the most of the ferries (81%), *DW* range from 2000 to 8000 t. Compared to other types of ships of similar size, *DW* of ferries is considerably smaller due to the relatively light mass cargo with a large stowage factor. Only two ferries have *DW* above 14000 tons, and one of them is intended for the transport of trains so this explains the *DW* over 18000 tons. Figure 10. shows the relationship between *DW* and L_{OA}. *DW* of Ro-Pax ferries can be approximately determined by the equation:

$$DW = 0.1866 \cdot L_{OA}^2 + 2.4361 \cdot L_{OA} - 655.67 \quad (4)$$

The value of the R^2 coefficient is 0.4492, so this formula should be used only as some kind of guideline.

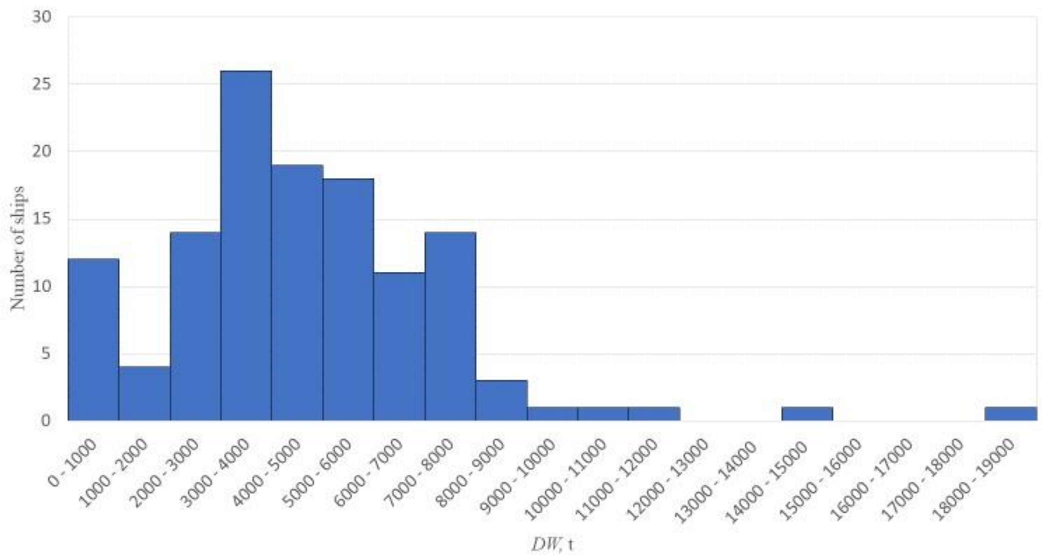

Figure 9. *DW* and number of Ro-Pax ferries

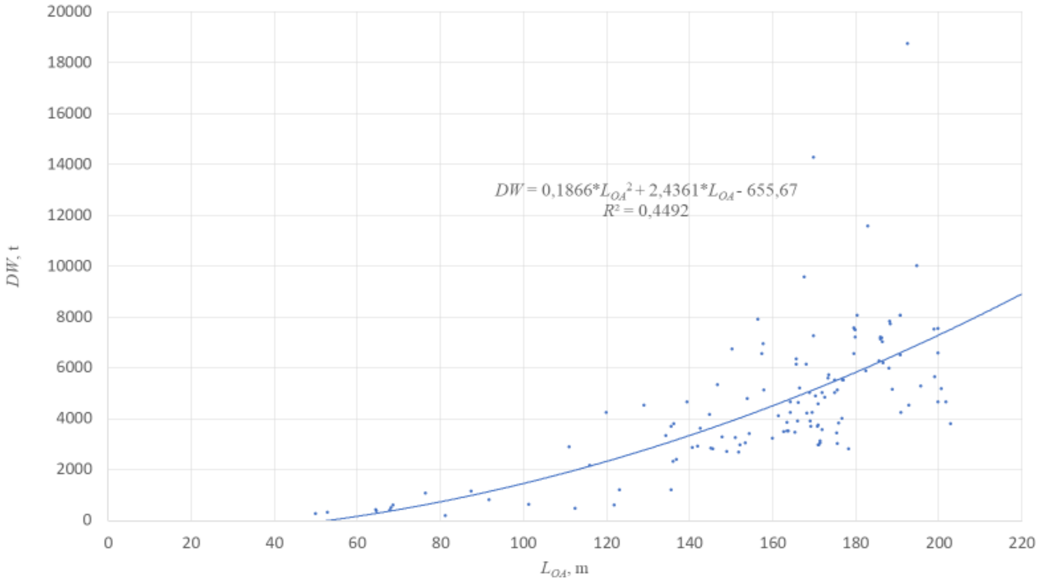

Figure 10. *DW* as a function of L_{OA}

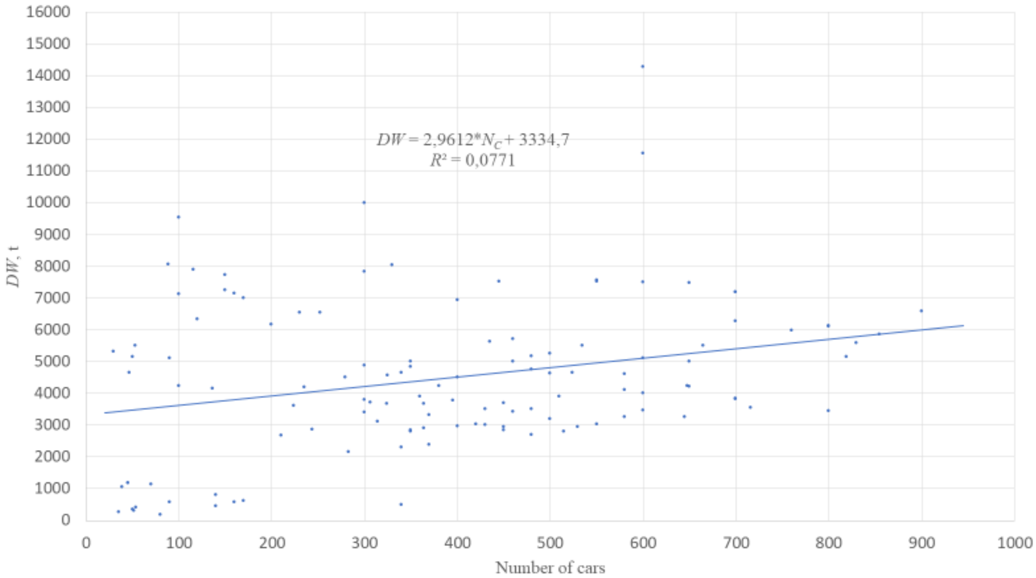

Figure 11. *DW* as a function of number of cars (N_C)

Due to very various routes, the Ro-Pax ferry capacities are very heterogeneous. The different routes show different needs of capacities. Some routes require higher passenger capacity at the expense of smaller vehicle capacity, and vice versa and this partially explains the large scatter of data in Figure 11. The formula shown on Figure 11. practically cannot be used due to very low value of the R^2 coefficient which is 0.0771.

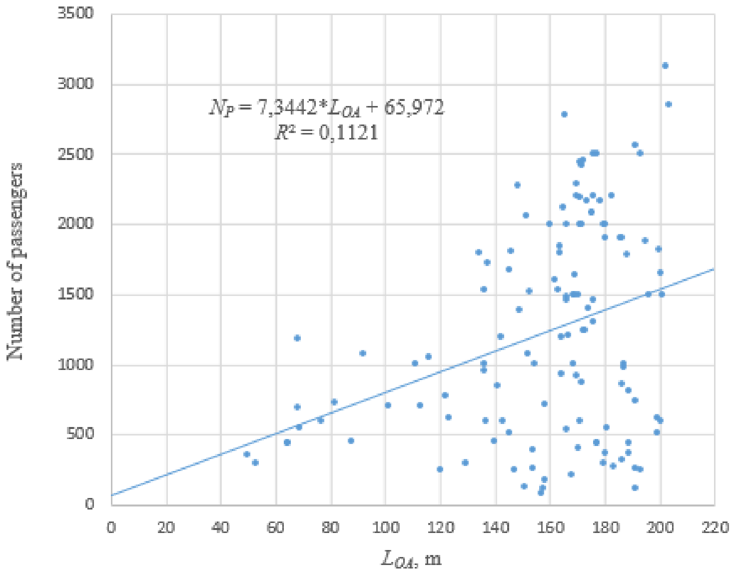

Figure 12. Number of passengers (N_P) as a function of L_{OA}

As already mentioned, Ro-Pax ferry capacities mostly depend on route demands and therefore passenger and car capacities vary from ferry to ferry. Consequently, it is difficult to connect these capacities with L_{OA}, as shown in Figure 12. There is some dependency between the passenger or car capacities and L_{OA}, but there is no strong correlation since the values of the R^2 coefficient are very low: 0.1121 and 0.2329. The passenger capacities for ferries between 120 and 200 m range from 79 to 3123, with the average value of 1316 passengers. As far as car capacities are concerned, they range from 30 to 900, with the average value of 425 cars, Figure 13.

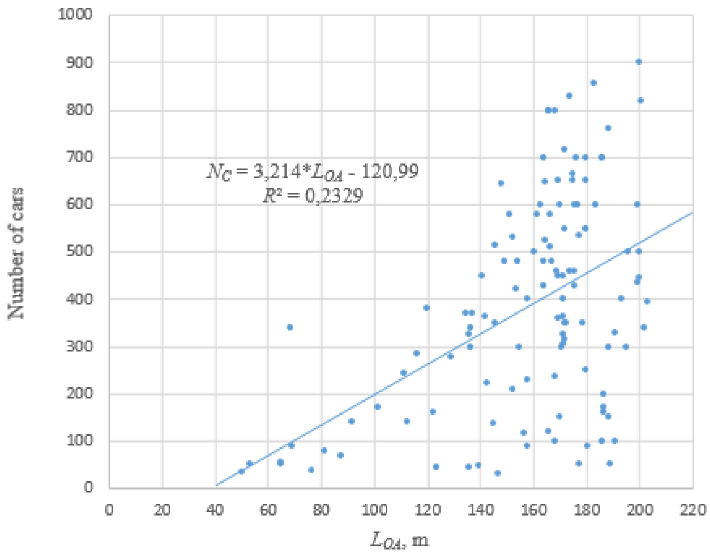

Figure 13. Number of cars (N_C) as a function of L_{OA}

P significantly depends on the L_{OA} and P increases with increasing L_{OA}. Likewise, the ship speed undoubtedly determines the selection of the main engine and usually P is a nonlinear function of V. Figure 14. shows the P in relation to the L_{OA}. P of Ro-Pax ferries can be approximately determined by the formula:

$$P = 0.8334 \cdot L_{OA}^2 - 6.2693 \cdot L_{OA} - 350.34. \quad (5)$$

The value of the R^2 coefficient is 0.4508, so this formula also should be used with caution. It can be noticed that the regression curve tracks data well up to 150 m. For larger ferries, the data scatter is too large, which can be explained with different ferry mission profile and speed requirements. P for ferries with the L_{OA} between 50 to 200 m varies from 8700 up to 50400 kW.

Similarly as P, V can also be presented with the regression function in regard to L_{OA}, Figure 15. It can be noticed that the scatter of data is too large, particularly for L_{OA} over 150 m. These disparities in V are mostly caused by lengths of routes and mission profiles of ferries. V for ferries with L_{OA} between 150 and 200 m range from 10.7 to 28.5 knots, with average of 19.4 knots.

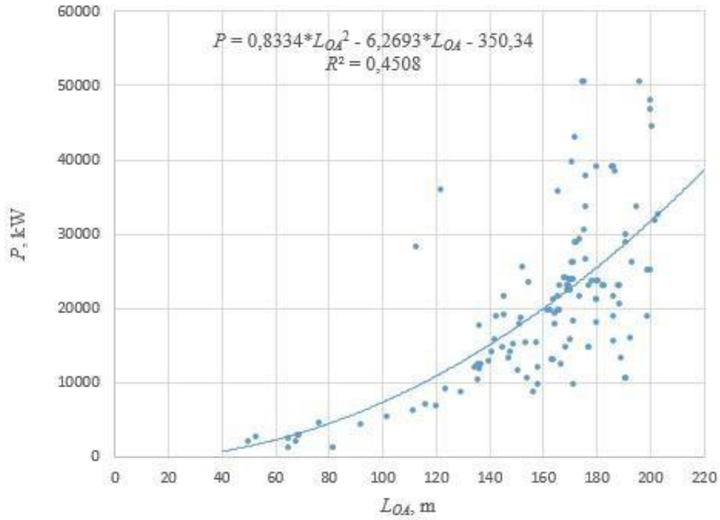

Figure 14. P as a function of L_{OA}

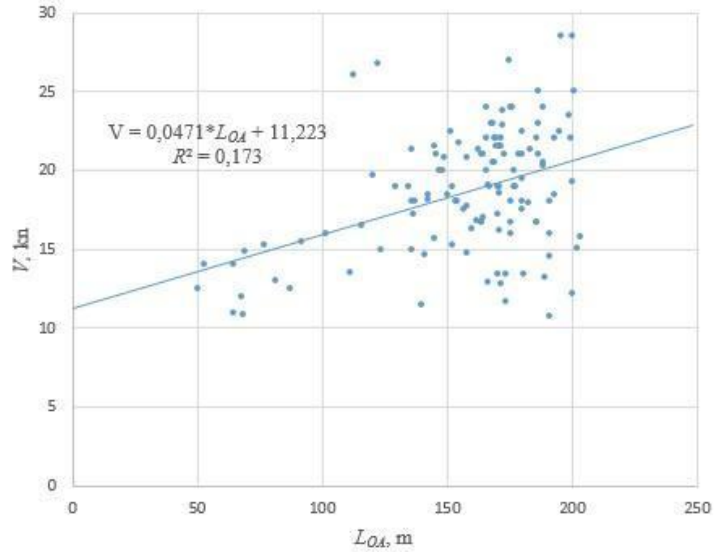

Figure 15. V as a function of L_{OA}

4. GUIDELINES FOR THE CONCEPT DESIGN OF HYBRID FERRIES

Results obtained from the analysis of established database were used for the estimation of basic parameters of hybrid Ro-Pax ferry which was destined to be developed within the project METRO. This ferry is intended to operate on a route that was taken as relevant for the project METRO [11]. The route, with the length of about 130 nautical miles, should connect Croatia and Italy between ports of Split and Ancona. 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.

Table 1. Ro-Pax ferry – route Split and Ancona

Ro-Pax						
Basic parameters	**M/V Aurelia**	**M/V Marco Polo**	**New design**			
L_{OA}, m	147.97	128.13	120.00	125.00	130.00	135.00
B, m	25.40	19.60	21.060	21.580	22.110	22.630
T, m	5.80	6.20	4.850	4.990	5.120	5.260
GT	21518	10154	12780	14106	15474	16885
DW, t	3250	1132	2324	2565	2815	3074
IMO number	7602120	7230599	-	-	-	-
Build year	1980	1973	-	-	-	-
Passenger capacity	2280	1000	947 *	984 *	1021 *	1057 *
Car capacity	610	270	265 *	281 *	297 *	313 *
P, kW	14120	15000	10898.3	11887.9	12919.1	13992.0
V, kn	15.5	16.0	16.8	17.1	17.3	17.6

* - To be taken with caution.

5. CONCLUSION

One of the main goals of the METRO project is the development of new hybrid Ro-Pax ferry, which may be suitable for the transportation of passengers and vehicles between ports in Italy and Croatia 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 both types of ferries were gathered, the databases provide very good guidelines for 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 Ro-Pax 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

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