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Basic plan dimensions of marinas in Croatia

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Subject review

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The analysis and presentation of plan view parameters for 39 marinas operating in Croatia is made in the paper to enhance improvement of the spatial and economic planning of nautical tourism in Croatia. The following plan view parameters were collected: number of berths, number of dry berths, breakwater length, fixed pier length, pontoon length, waterfront length, water basin area, territory area, total area, dry berth area, and parking area. The dependence of these parameters on the number of sea berths is presented, and average statistical indicators of these parameters, which characterise marine construction in Croatia, are defined.

Key words:
marina, pier length, territory area, water basin area, breakwater length, construction costs

Pregledni rad

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Tehničko-ekonomski parametri marina u Hrvatskoj

Radi unapređenja urbanističkog i ekonomskog planiranja nautičkog turizma u Hrvatskoj, u ovom je radu provedena analiza i prezentacija tlocrtnih parametara 39 postojećih hrvatskih marina. Prikupljeni tlocrtni parametri su: broj vezova, broj suhih vezova, duljina lukobrana, duljina fiksnih gatova, duljina pontona, duljina obala, površina akvatorija, površina teritorija, ukupna površina, površina suhog veza i površina parkirališta. U radu su prikazane ovisnosti navedenih parametara u funkciji broja vezova u moru te su definirani prosječni statistički pokazatelji navedenih parametara koji karakteriziraju gradnju marina u Hrvatskoj.

Ključne riječi:
marina, duljina gatova, površina teritorija, površina akvatorija, duljina lukobrana, troškovi gradnje

Übersichtsarbeit

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Typische Maßen der Grundrisse kroatischer Marinas

Um die urbanistische und wirtschaftliche Planung des nautischen Tourismus in Kroatien zu verbessern, sind in dieser Arbeit die Parameter der Grundrisse für 39 bestehende kroatische Marinas analysiert und dargestellt. Die zusammengestellten Parameter der Grundrisse umfassen: die Anzahl der Liegeplätze, die Anzahl der trockenen Liegeplätze, die Wellenbrecherlänge, die Länge der festen Pfeiler, die Länge der Pontons, die Küstenlänge, die Wasserfläche, die Grundstücksfläche, die gesamte Fläche, die Parkfläche und die Trockenliegefäche. In der Arbeit wird die Abhängigkeit dieser Parameter von der Anzahl der Liegeplätze erläutert und durchschnittliche statistische Indikatoren werden definiert, die den Bau von Marinas in Kroatien charakterisieren.

Schlüsselwörter:
Marina, Pfeilerlänge, Grundstücksfläche, Wasserfläche, Wellenbrecherlänge, Baukosten

1. Introduction

Nautical tourism is a type of tourist activity that is intensively linked to the sea and navigation, and is generally defined as a "multifunctional tourism-oriented activity, with a highly pronounced maritime component" [1]. Nautical tourism is a multidisciplinary activity that has been studied not only from the economic and maritime standpoints, but also from the standpoint of civil engineering [2]. As to its classification, nautical tourism can be divided into: 1. nautical tourism ports, 2. charter, and 3. cruising. Nautical tourism ports are the very focus of civil engineering researches, as these ports are in fact structures in the sea, as well as structures on the shore along the sea. The development of nautical tourism is defined on the strategic level in [3] where the following plan is emphasized: within the oncoming ten-year horizon, five thousand new berths must be built in the existing ports, five thousand berths must be built on locations appropriately distributed along Croatian coast and islands, and five thousand places for dry accommodation of vessels on the shore should also be constructed". By the year 2013 Croatia had 106 nautical tourism ports (mooring places, berths, dry marinas, and marinas) along the sea coast, i.e. 67 marinas (14 dry marinas) and 39 other nautical tourism ports [7]. It had the total of 16940 berths in the sea and 5473 places for accommodating vessels on the shore. This classification (mooring places, berthing places, dry marinas and marinas) as cited in [7] was used in the old legislation [11] according to which most marinas covered in this paper are categorized (1-3 anchors). According to the new law [12] enacted in 2008 nautical tourism ports are classified as mooring places, vessel storage facilities, dry marinas, and marinas, and the categorization is made according to different criteria.

There is a pressing need for establishing new nautical capacities in Croatia, which is currently defined on the strategic level only [3]. In order to enable proper nautical tourism development planning, in compliance with sustainable development principles [15, 16], the civil engineering profession must provide an appropriate contribution, and this contribution will in fact be the primary objective of this paper. More specifically, the objective is to define average plan-view parameters for marinas in Croatia, which will constitute the basis for future urban development planning and preparation of other relevant studies. In addition, marina construction cost estimates will be provided below in relation to the number of berths, which can be a suitable basis for selecting locations of future marinas, comparing plan-view alternatives, etc.

2. Definitions

Basic plan-view dimensions for the existing thirty-nine Croatian marinas were collected in the scope of this paper, and this by using national infrastructure spatial data tools [5] and available browsing capabilities [4]. Considering the limited possibility of detecting some structural parts of marinas using the above browsing capabilities, the data base covers 39 out of the total of 53 marinas, i.e. the data base takes into account only the marinas for which appropriate data were available. It is believed that the sample of 39 marinas is sufficiently large to represent statistical variables for the entire territory of Croatia. Plan view dimensions collected are given with appropriate definitions:

NUMBER OF BERTHS – this value was obtained from [8] and it includes permanent berths, transit berths, and servicing berths.

NUMBER OF PLACES FOR ACCOMMODATING VESSELS ON THE SHORE (DRY BERTHS) – this value was obtained from [8] and it includes areas developed for providing accommodation to vessels on the shore.

BREAKWATER LENGTH – measured breakwater length including the main and secondary breakwaters (rubble mound breakwaters, vertical breakwaters on piles, vertical gravity type breakwaters)

FIXED PIER LENGTH – measured length of all fixed piers where vessels can be moored (piers on piles, gravity piers). It should be noted that the length means the length of the structure rather than the length of the mooring line.

PONTOON LENGTH – measured length of all pontoon piers that are used for mooring vessels. It should be noted that the pontoon length means the length of pontoons rather than the length of the mooring line.

PIER LENGTH – is the total length of all piers including fixed piers and pontoons.

WATERFRONT LENGTH – is the measured length of developed waterfront including all types of waterfronts with and without mooring capability (waterfronts on piles, rip-rap revetments, gravity walls, slipways).

SEA BASIN AREA – measured area of water bordered with boundary structures (breakwaters or piers) incliuding the area of piers and pontoons.

TERRITORY AREA – measured area of all components situated outside of the water (area of dry berths, parking lots, buildings, service stations, and other areas).

TOTAL AREA – sum of sea basin and territory areas

DRY BERTH AREA – measured dry berth area including storage areas, service areas, crane or travel-lift areas, access roads and service roads.

PARKING LOT AREA – measured parking-lot and access-road areas.

Analysed marinas: Umag, Rovinj, Pula, Pomer, Opatija, Cres, Supetarska D., Rab grad, Pag (Šimuni), Žut, Piškera, Jezera, Vodice, Skradin, Trogir, Split, Milna, Palmižana, Vrboska, Korčula, Dubrovnik, Punat, Veruda, Dalmacija, Borik, Preko, Sutomiščica, Šangulin, Kornati, Hramina, Danuvius, Kremik, Frapa, Kaštela, Mandalina, Betina, Admiral, Červar porat, Novigrad.

3. Analysis of plan-view properties of structural parts of Croatian marinas

The following basic structural parts of marinas are introduced for the purposes of this paper: parking lot, dry berth, mooring structures (fixed piers and pontoons), breakwaters and buildings. This classification is appropriate for the method used for obtaining data from the sources [4, 5] and for cost-estimate analyses. Sea basin and territory areas were additionally analysed as a basis for the preliminary design of marinas.

3.1. Sea basin and territory areas occupied by marinas

Total measured areas, territory areas, and sea-basin areas, are related to the number of berths in the sea (Figure 1). An expected trend of increase of typical areas with an increase in the number of berths in the sea can be observed. Measured values were fitted with regression lines by forcing line passage through the origin of the coordinate system. Thus the logical requirement that the area equals 0 for the 0 number of berths has been met. The quality of agreement of regression lines with regard to measured values was estimated using the determination coefficient R^2. It can be observed that regression lines describe measured values quite well if $R^2 \geq 0.5$.

The measured data set has much more values for small and medium–sized marinas (between 100 and 500 berths) compared to big and very big marinas (from 500 to 1200), for which only several data are available. This is due to the fact that there are very few large marinas in Croatia with > 500 berths. According to [6], Croatia has on an average smallest marinas (together with Malta) with 284 berths/marina on an average, while the European average for twenty leading countries is 473 [berths/marina]. Biggest marinas are situated in France and Spain, with 801 [berths/marina] and 508 [berths/marina], respectively.

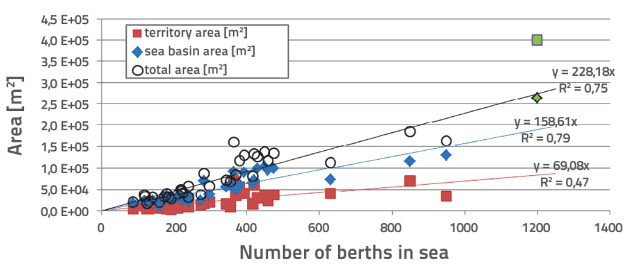

Figure 1. Measured areas of Croatian marinas with appropriate adjustment lines (green values are outliners, and belong to the Marina Dalmacija – Sukošan) [4, 5]

If the inclination of straight line (Figure 1) is adopted as an indicator of average area typical for Croatian marinas, then the following conclusions can be made:

a) an average area occupied by marinas in Croatia is -230 [m²/berth in the sea],

b) an average area of the territory is -70 [m²/berth in the sea],

c) an average area of the sea basin is -160 [m²/berth in the sea].

The following values recommended by the international professional committee PIANC [9] are given for comparison purposes: the total area is 208 [m²/berth in the sea], territory is 72 [m²/berth in the sea], and sea basin is 136 [m²/berth in the sea]. This comparison shows that the areas of Croatian marinas are generally compliant with PIANC recommendations.

Figure 1 also shows that Croatian marinas are built in such a way that the territory accounts for about 30 % of the total area of a marina, while the sea basin accounts for 70 %. This relationship should tend toward 50 % / 50 %, which is recommended in [10] so as to increase marina contents on the shore (amusement areas, sporting grounds, restaurants, shops, hotels, servicing facilities, and other services).

3.2. Parking lot and dry berth

Parking areas and dry berths are important functional parts of marinas. The dependence between the number of dry berths and the number of parking places, as related to the number of berths in the sea, is shown in Figure 2. The trend of increase with an increase in the marina capacity can normally be expected. The sample with the data on parking places is limited due to unavailability of data.

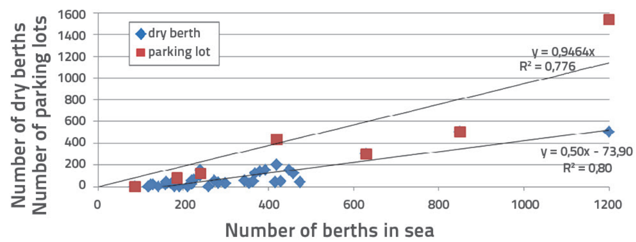

Figure 2. Number of dry berths [8] and parking places as a function of the number of berths in the sea

The regression line that represents the dry berth is fitted without forcing the passage of the line through the origin, because dry berths are not planned in many small marinas (< 150-200 berths in the sea). In fact, it would not be realistic if the theoretical function were to provide dry berth values in the area of small marinas. Due to limited territory or poor accessibility (islands), such marinas usually do not offer servicing (repair and maintenance) and dry berth services. On the other hand, the regression line for parking places passes through the origin as, according to [11, 12], parking lots are anticipated even for smallest size marinas as a percentage in the total number of berths.

It can be concluded from regression lines (Figure 2) that Croatian marinas are characterized by the relationship 1 [park/berth in the sea], and by relationship $y = 0.5\,x - 74$, considering that dry berths occur in case of marinas with >150 berths in the sea. For comparison purposes, it should be noted that 0.78-1.3 [park/berth in the sea] and 0.6 [dry berth/berth in the sea] is required according to [9].

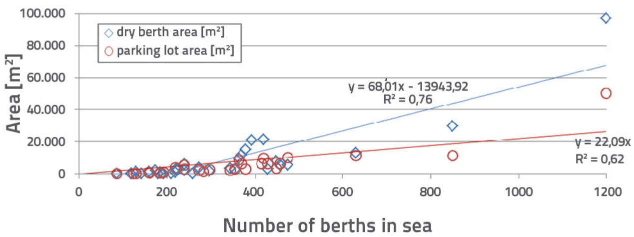

Figure 3. Measured dry berth and parking lot areas in Croatian marinas [4, 5]

Measured dry berth and parking lot areas, as related to the number of berths in the sea, are shown in Figure 3. Regression lines show that parking lots account for 22 [m²/berth in the sea] in Croatian marinas, and that the dry berth area is define according to the expression y = 68, 1x-13943.9. According to [9], these values for parking lots amount to 19 [m²/berth in the sea], while for dry berth these values are 53 [m²/berth in the sea].

3.3. Piers and waterfronts

The length of developed waterfronts is shown in Figure 4. This includes all types of developed waterfronts with and without mooring capabilities. The data collection method applied does not allow detailed registration of lengths for different types of structures. Figure 4 shows the total length of piers (different types of structures) as a function of the number of berths in the sea. This approach has enabled establishment of the functional dependence between the required length of mooring structures (piers) and the number of berths in the sea. Both sets of data increase with an increase in the mooring capacities. Regression lines show that Croatian marinas are characterised by an average waterfront length of 1.9 [m/berth in the sea], and by the pier length of 2.1 [m/berth in the sea].

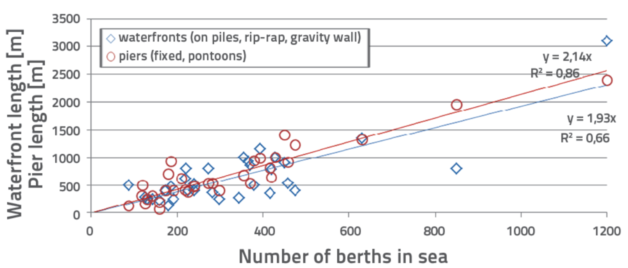

Figure 4. Measured lengths for developed waterfronts, fixed piers, and pontoons, as a function of the number of berths in the sea [4, 5]

It should be noted that the values shown in Figure 4 do not include piers with one-sided mooring capability, which are used in this way for some special reasons (protection against waves, pontoons anchored to the waterfront, etc.), as in this case values with a dramatically greater relationship between the pier lengths per berth in the sea would be obtained. Figure 5 shows pontoon or pier length relationship as a function of the number of berths in the sea, where figures for piers and pontoons with one sided mooring capability are included (rounded values in the Figure). It can be noted that lengths of mooring structures per berth range from 3 to 4.3 m/berth, unlike marinas with better utilisation of mooring structures, where this relationship varies from 2 to 2.5 m/berth, which is in accordance with the statistically representative value shown in Figure 4.

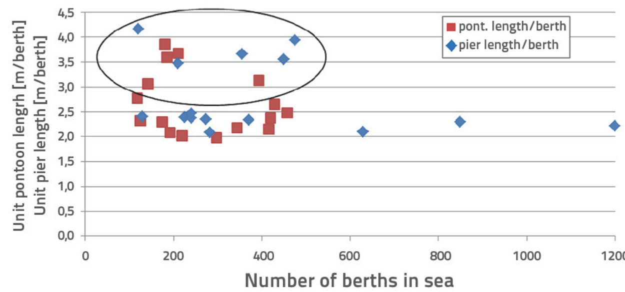

Figure 5. Relationship between the unit length of pontoons or piers as a function of the number of berths in the sea [4, 5], rounded values are related to marinas with one-sided mooring of vessels onto piers or pontoons

3.4. Breakwaters

The length of protective structures (breakwaters) is not only dependent on the number of berths in the marina, but also on the level of protection of the locality. This is why breakwaters are classified according to the class of exposure. Three classes of exposure are envisaged: Class 1 (for the effective fetch of < 1 km), Class 2 (effective fetch varies from 1 to 5 km), and Class 3 (effective fetch is > 5 km). The effective fetch is determined according to the method defined in [13] using only three rays out of which the central one is oriented in the direction of the dominant wind (bura, sirocco, mistral or libeccio), while the other two are at 30° to each side from the central ray. This method is an adaptation of the original method [13] to the data collection conditions, and can therefore be regarded as representative for this paper.

The dependence between the breakwater length and the number of berths in the sea was defined in accordance with these classes (Figure 6). As could have been expected, the exposure class 3 provides the greatest breakwater length for the same marina capacity, while lower classes provide lower values. A considerable dispersion of data is due to the fact that not all parameters defining the protective structure length have been included in the analysis. In fact, the length of protective structure is normally defined on the basis of calculation of wave deformations, which is not unambiguously defined by the fetch length as it actually depends on the wind frequency, velocity and direction, on the sea depth, and also on the coastline configuration. Higher dispersion is detected by low coefficient of determination R^2.

Regression lines show that an average breakwater length of 1.2 [m/berth in the sea] is needed for the exposure class 3, the length of 0.6 [m/berth] is needed for the class 2, and 0.1 [m/berth in the sea] is required for the class 1.

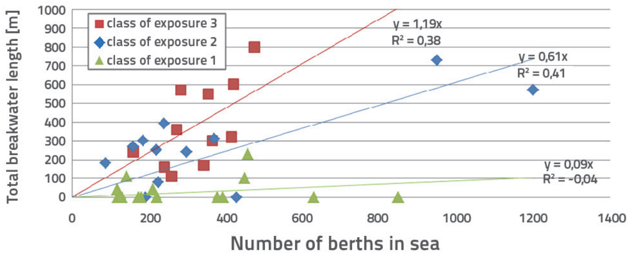

Figure 6. Measured breakwater length values (rubble mound breakwaters and vertical breakwaters) as a function of the number of berths in the sea [4, 5]

The data analysis shows that the total relationship between the length of rubble mound breakwaters and vertical breakwaters (gravity type, on piles) amounts to 60 % / 40 %.

3.5. Buildings

The method applied in the paper did not enable accurate definition of the area of buildings and their functions, which is why these parameters were not analysed. Building areas are included in the territory area (Figure 1).

4. Research results

4.1. Marina construction cost estimate

Based on the data presented in the previous section, an estimate of marina construction costs is presented below, as a contribution to the economic analysis of marinas regarded as nautical tourism ports of Croatia. The basic assumption of this simple cost estimate model is that the size of individual structures (breakwater, waterfront, pier, parking lot, and dry berth) is a function of the number of berths in the sea, and that they are defined with regression lines given in the above-presented diagrams.
The dependence of the size (useful area) of the building on the number of berths in the sea is represented with the gross area of 4 [m²/berth in the sea], according to the estimate made by the authors of this paper. All other costs including necessary installations, landscaping, specific foundation costs, design costs, and unforeseen costs, are estimated at 10 percent of the price. The price of land is not taken into account in this approach. The unit price of the breakwater is taken to vary with the depth (d = 5, 10 and 15 m), while a fixed unit price – regardless of the depth - is adopted for piers and waterfronts (piers and waterfronts amount to d = 4 m and d = 2.5 m, respectively). This assumption is acceptable because the unit price increase with the waterfront/pier depth is negligible compared to the total price.

The unit rates used in this estimate are based on the multiannual database kept by the Faculty of Civil Engineering – University of Zagreb.
Calculation results are shown in the diagram (Figure 7) for three classes of marina exposure, and for three average protective-structure depths (d = 5, 10, and 15 m). The same diagram shows the function of marina costs, without protective structures (breakwaters). It can be seen that marinas belonging to the third class of exposure (effective fetch > 5 km) are the most expensive because of the most stringent requirements with regard to the length of protective structures. It is also obvious that the total price progressively rises at the depths of more than d = 10 m. Marinas without protective structures (naturally protected marinas) exhibit much lower construction costs compared to marinas belonging to exposure classes 3 and 2, which shows that the proportion of this element in the total construction price of marinas can be significant. Marinas belonging to the exposure class 1 are close to the price-range of marinas without protective structures, as here the breakwater length is relatively short.

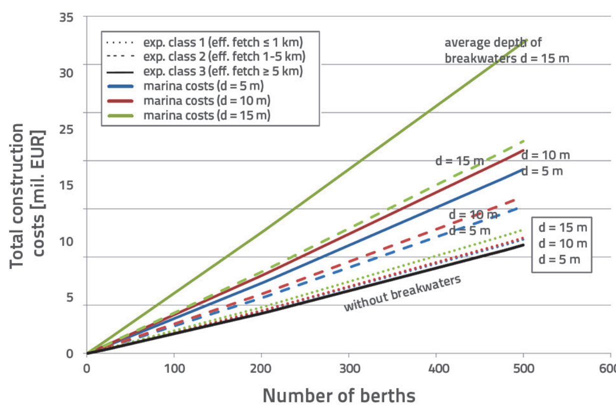

Figure 7. Dependence of construction costs on the number of berths in the sea (eff. = effective)

The proportion of individual structures in the total marina construction price is graphically presented in Figure 8. This figure shows a marina with an average protective structure depth of d = 10 m, and with the capacity of 300 berths in the sea. In the exposure class 3, the breakwater price attains 45 % of the total construction price, and the prices decrease with an increase in the level of protection of the marina site. Other items that form a significant part of the construction price are the waterfront, building, and piers and, finally, the parking lot, dry berths, etc. are the items with smallest proportion in the price It should be noted that the values given in Figures 7 and 8 are based on certain assumptions and simplifications, and that the real-life relationships and prices may vary considerably form the presented prices, depending on the sea depth, site exposure, foundation requirements, specific market conditions, etc. These diagrams can be used only for strategic planning at the national level, and thus are not appropriate for specific localities/sites.

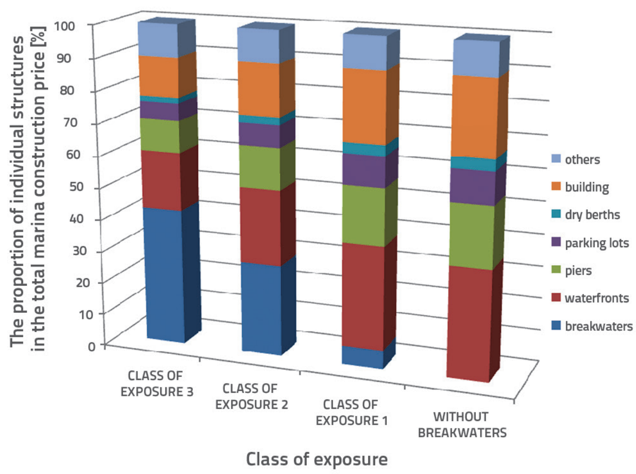

Figure 8. Relative proportion of individual structures in the total construction price of marinas, as based on exposure classes (an average breakwater depth of d=10 m is applied, and 300 berths)

4.2. Average nautical fleet in Croatian marinas

The analysis of data given in [7] about the nautical fleet encountered in Croatian marinas revealed values that are presented in Figure 9.

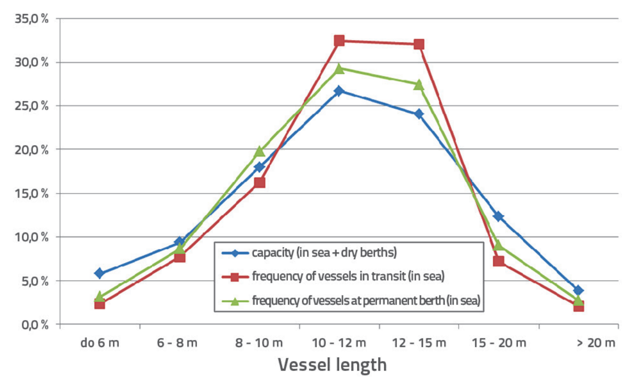

Figure 9. Capacity, frequency of vessels in transit, and frequency of vessels at permanent berth, in nautical tourism ports (marinas, dry marinas, mooring sites and berthing sites), average for 2010-2013

These values generally refer to nautical tourism ports including marinas, dry marinas, mooring sites, and berthing sites. A relative correspondence can be noted between the port capacity and frequency of vessel occurrence at permanent berths or in transit, which means that the capacities offered are in good agreement with the demand. This diagram is also a guideline for the design of future capacities as envisaged in the corresponding strategy [3]. We should also take into consideration a relatively small number of vessels in the category of more than 20 m in length, which is highly significant from the civil engineering point of view. This category comprises mega-yachts (30 - 60 m) and super-yachts (>60 m), which are increasingly seen in marinas over the past decade. Mega-yachts and super-yachts account for a relatively small number of vessels but require a significant space in ports for manoeuvring and mooring [14].

5. Conclusion

Plan-view parameters for marinas, obtained through inspection of aerial maps, are analysed and presented in the paper. Parameters gathered in this way were used to define representative statistical parameters of plan-view dimensions of Croatian marinas. It was established that an average capacity of marinas in Croatia amounts to 283 berths/marina, which is one of the lowest capacities in Europe (European average is 473 berths/marina). The relationship between the territory and sea basin is 30 % / 70 %, which is a relatively low relationship that is to be increased by extending on-land services. An average territory size is 70 m^2/berth in the sea, while an average sea basin size is 160 m^2/berth. One parking place per berth is usually provided in Croatian marinas. An average pier length is 2.1 m/berth in case of an optimum two-sided mooring of vessels onto piers or pontoons, while this length reaches up to 4 m/berth in case of one-sided mooring solutions.

In addition to the number of berths, the length of protective structures (breakwaters) in marinas is also dependant on the exposure of marina site. The corresponding calculations show that an average length of a protective structure amounts to 1.2 [m/berth in the sea] for the exposure class 3 (effective fetch > 5 km), 0.6 [m/berth] for the exposure class 2 (effective fetch from 1 to 5 km), 0.1 [m/berth] for the exposure class 1 (effective fetch < 1 km). The analyses made in the scope of the paper show that top statistical values were defined based on the data with great dispersion, which would mean that the proposed classification method is robust, and that it requires introduction of additional parameters (wave deformation analysis, long-term wave forecast) so that more suitable results can be obtained.

The analysis of marina construction costs shows that in case of marinas exposed to wave action the breakwater price is actually the most important component, as it can amount to 45 % or more of the total cost for breakwaters with an average depth of d = 10 m. It was also established that the breakwater price increases progressively for the depths of more than d = 10 m. As to other prices, the most significant is the price of waterfront, which is followed by the price of buildings and piers.

The study of the frequency of vessels at berth and in transit through Croatia for 2010 – 2013 shows that most frequent vessels measure 10-15 m in length. An emphasis should however be placed on the growing number of mega-yachts and super-yachts that are highly demanding with regard to sea space they require in marinas.

The data collected by measuring lengths and areas of basic structural elements in marinas, based on direct aerial map surveys, constitute the basis of this study. The data gathering methodology is rapid, efficient and practically free of charge, and can therefore be recommended for other investigations of this kind. Further research is nevertheless needed in this area, namely in order to expand the existing data base, and to gain better insight into other factors that influence the total cost of breakwaters in marinas and municipal ports.

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