DETERMINING NAUTICAL ANCHORAGE LOCATIONS USING MULTI - CRITERIA ANALYSIS

Pušić, Danijel

FACULTY OF MARITIME STUDIES

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DOCTORAL THESIS

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Supervisor: Zvonimir Lušić, Ph.D.

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IMPRESSUM

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Supervisor: Zvonimir Lušić, Ph.D., full professor, Faculty of Maritime Studies, University of Split

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DATA ON EVALUATION AND DEFENCE OF THE DISSERTATION

Doctoral dissertation evaluation committee:

1. Ivica Skoko, Ph.D., president, assistant professor, Faculty of Maritime Studies, University of Split
2. Ivana Racetin, Ph.D., member, full professor, Faculty of Civil Engineering, Architecture and Geodesy, University of Split
3. Marko Perkovič, Ph.D., member, assistant professor, Faculty of Maritime Studies and Transport, University of Ljubljana
4. Rino Bošnjak, Ph.D., reserve member, associate professor, Faculty of Maritime Studies, University of Split

Doctoral thesis defence committee:

1. Ivana Racetin, Ph.D., president, full professor, Faculty of Civil Engineering, Architecture and Geodesy, University of Split
2. Marko Perkovič, Ph.D., member, assistant professor Faculty of Maritime Studies and Transport, University of Ljubljana
3. Ivica Skoko, Ph.D., member, assistant professor, Faculty of Maritime Studies, University of Split
4. Rino Bošnjak, Ph.D., member, associate professor, Faculty of Maritime Studies, University of Split

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STATEMENT ON DOCTORAL THESIS ORIGINALITY

I declare that my doctoral thesis is the original result of my work and that it clearly states and cites the references of contributions and papers by other authors[1]. I also declare that I have fulfilled all the conditions for initiation of the procedure of evaluation and defense of the doctoral thesis, including those related to the publishing and presentation of papers from the doctoral thesis research area[2].
I declare that the proposed doctoral thesis has been formatted according to the Instructions for doctoral thesis formatting.

Danijel Pušić

(First and last name of doctoral candidate, signature)

SUPERVISOR BIOGRAPHY

Zvonimir Lušić, PhD, was born on December 6, 1971, in Trogir, Croatia. He is a Croat by nationality and a citizen of the Republic of Croatia. He is married and father of two children. He graduated from high school in Split from the Higher Maritime School in Split in 1993 and from the Faculty of Maritime Studies in Split in 2007, where he obtained the professional title of graduate marine transport engineer in the field of nautical science. In the following years he served on merchant ships in international shipping as a deck officer, with later activities being related to management and finally the training of seafarers. In 2002, he enrolled the postgraduate master's study in "Technological Systems in Maritime Transport" at the Maritime Faculty of the University of Rijeka, graduating in 2006. He resumed the postgraduate doctoral study in "Technological Systems in Maritime Transport" at the Maritime Faculty of the University of Rijeka in 2007. On July 19, 2010, he completed his doctoral studies by writing the dissertation entitled "A Contribution to the analysis of the safety and economic factors influence on marine voyage optimization" under the supervision of prof. Ph.D. Serđo Kos and obtained the academic degree of Doctor of Science in the scientific area of Technical Sciences, the scientific field of Traffic and Transport Technology, the discipline of Maritime and River Transport. Since May 1, 2005, he has worked at the Faculty of Maritime Studies in Split, where he worked first as a lecturer, later as a senior lecturer, assistant professor, associate professor and, eventually, full professor. He teaches at undergraduate and graduate levels, including the doctoral study, mainly covering the area in navigation subjects. From 2009 to 2014 he was the Head of Nautical Studies, and since 2014 he has been the Head of the Nautical Department. He is listed in the Register of Scientists at ID number 288482. His published works are available at the link: https://www.bib.irb.hr/pretraga?operators=and|Lu%C5%A1i%C4%87,%20Zvonimir%20%2822975%29|text|profile

ABSTRACT

Since moorings and anchorages for vessels have recently become an important factor in nautical tourism, selecting their future locations is a complicated and responsible process. In this doctoral dissertation, numerous criteria are analysed to determine the most favourable locations of anchorages, meeting the conditions prescribed by the recommendations but at the same time meeting the expectations of the future users, spatial planners, possible investors and concessionaires who would operate in these areas, as well as the entities that strive to preserve and protect marine life and the environment and prevent its degradation and pollution. However, since there are no precisely defined recommendations for the establishment of nautical anchorages, the procedures for determining the location of nautical anchorages may feature the general criteria that must be met. A comparative analysis of several methods of multi-criteria analysis (MCA) using a number of criteria shows that the determination of the best locations of nautical anchorages requires a specific and systematic approach and professional knowledge of several different fields, including the knowledge and expertise in the fields of spatial planning and construction, seafaring, maritime safety, maritime traffic, architecture, geodesy, shipping, biology, ecology, mathematical programming, operational research, information technology, environmental protection, as well as other expertise profiles. The best locations of nautical anchorages should be selected based on the size, number of vessels, available space, depth, distance from the coast, degree of protection of the waters, and many other limiting factors, recognising that those locations that simultaneously meet a greater number of important criteria are better. As part of the marine water area, the anchorage provides safe anchoring for vessels and is one of the links in the maritime transport infrastructure, particularly in nautical tourism. The basic purpose of anchorage comes from the definition that implies safe anchorage, which is also the basic assumption and condition without which it has no purpose. Anchorages can be divided according to their purpose, and the basic division is into nautical anchorages and anchorages for ports open to public traffic. The anchorage is a part of the water area equipped for the berthing of vessels in a bay or cove protected from the weather, so safe anchorages are mostly located in such areas. Open anchorages are located in unprotected waters and are intended for short stays of vessels. These anchorages are used for ports open to public traffic and are not equipped with commercial infrastructure. This doctoral dissertation will investigate the methods of MCA in the selection of the best locations for future concession fields of nautical anchorages. The possibility of obtaining an optimal solution in the process of selecting the locations from a group of possible ones will be explored by methods of

MCA, evaluation and classification of criteria, and assignment of weight values to selected criteria. The most important criteria when applying MCA methods will refer to the criteria of the safety of navigation, hydrometeorological, spatial, economic, and environmental criteria. This approach allows for comprehensive and systematic problem-solving in order to achieve optimal solutions when determining the best future areas for nautical anchorages. The dissertation's main contribution is the proposal to optimise the decision-making process when determining the optimal locations of nautical anchorages based on the previously defined criteria.

Key words: Anchorage, Mooring areas, Multi-criteria decision-making, Location planning, Criteria, Weight coefficients, Concession fields, AHP method, TOPSIS method, AHP-TOPSIS-2N, PROMETHEE II

LIST OF LABELS AND ABBREVIATIONS

- AHP - Analytical Hierarchy Process
- BWM - International Convention for the Control and Management of the International Maritime Organization of Ships' Ballast Water and Sediments
- CI - Consistency Index
- CR - Consistency Ratio
- CRI - Consistency Ranking Index
- DMP - Decision-Making Problem
- DSS - Decision Support System
- ELECTRE III - Elimination Et Choice Translating Reality
- ES - Expert System
- EU - European Union
- GAIA - Geometrical Analysis For Interactive Aid
- GIS - Geographic Information System
- GW - Gigawatt
- IMO - The International Maritime Organization
- LNG - Liquefied natural gas
- MARPOL 1973/78 - The International Convention for the Prevention of Pollution from Ships, 1973/78
- MCA - Multi Criteria Analysis
- MCDA - Multiple-Criteria Decision Analysis
- MCDM - Multi-criteria decision method
- MS - Microsoft
- NOR - Notice of Readiness
- VAT - Value added tax
- PIA - Fields from the survey
- PIANC - The World Association for Waterborne Transport Infrastructure
- SDPMC - Spatial development plans of municipalities and cities
- PROMETHEE I, II, III - Preference Ranking Organization METHod for Enrichment Evaluation I, II, III
- PSC - Port State Control
- RCI - Random Consistency Index
- SDC - Split-Dalmatia County

- SMCE - Spatial Multi Criteria Evaluation
- SWOT - S-Strengths, W-Weaknesses, O-Opportunities, T-Threats
- TOPSIS - The Technique for Order of Preference by Similarity to Ideal Solution
- UKC - Under-Keel Clearance
- UNIX - UNiplexed Information Computing System
- VHF - Very High Frequency
- VTS - Vessel Traffic Services
- ZOC - Zone of Confidence

CONTENTS

1. INTRODUCTION

1.1. Problem, subject, goal, methods, and hypotheses

The world is characterised by a high degree of complexity. This unequivocal statement has significant implications for the way in which problems are presented and the way the decision-making and problem-solving processes are designed. Consequently, one can either take a simplistic approach by trying to tackle one of the many possible dimensions, or simply deal with the complexity and problems of the real world. This second approach is taken in this dissertation.

In some business decisions, negotiations and analyses would often be in vain, especially when it comes to large financial investments, and choosing and applying the most effective strategy that can ensure victory in negotiations, in the decision-making process or in choosing one option over another, considering that sometimes it is necessary to choose solutions that ensure the safest, not the most economical choice. In this context, it is useful to resort to mathematical optimisation methods to identify the best ways to overcome the stalemate in the decision-making process, to negotiate and choose the most favourable method in order to deal with the problem. Sometimes there are certain cases when the decision-makers have to choose among numerous alternatives, establish a hierarchy and select the best variants, offers, etc. In such cases, the multi-criteria decision-making (MCDM) methods are the most appropriate. This dissertation addresses the problem of studying and applying MCDM methods in the process of selecting the best locations for nautical anchorages planned as concession fields.

Spatial anchorage data is any type of data that directly or indirectly relates to the geographic area or location of the anchorage. Geospatial or geographic information about an anchorage site may be represented numerically as physical objects in a geographic (map) coordinate system.

Depending on meteorological and oceanographic parameters, anchorages are divided into sheltered/protected and exposed/unprotected. Sheltered anchorages are usually located in bays, inlets, or other natural areas providing a suitable ground for anchoring, where vessels are protected from wind and waves.

Unprotected anchorages are suitable for anchoring in good weather and calm condition.

In view of the safe anchoring and safety of navigation, a designated anchorage should have the seabed composition that allows for good anchor holding. It should be of depth sufficient for the expected vessels, yet not too deep, so that the anchor can hold well and the vessel can swing safely. Potential anchorages must be thoroughly inspected and researched to ensure accurate depth information, as the depth indicated on nautical charts is only general and does not provide an accurate estimate.

In this dissertation, the term "*vessel*" refers to any type of watercraft, including displacement vessels, multipurpose high-speed craft, and seaplanes, used or capable of being used as a means of transportation on water.

The physical nature of the seabed at the anchorage is highly important for ensuring safe and effective anchoring.

Anchorages, including mooring areas exposed to strong winds, tides, sea currents and/or heavy seas affect the ability of the vessel to manoeuvre safely to and from the anchorage and the ability of the anchor to hold the vessel in position.

The location of the anchorage should be such that it does not interfere with the existing allows for the safe passage of vessels through the channels and along the waterfront of the harbour and bay.

Anchorages should be kept clear of the existing and proposed infrastructure, underwater gas or water pipelines, underwater power and telecommunications cables, tunnels and overhead power lines and bridges. Anchorages must also be far enough away from other sources of danger so that the master of the vessel has sufficient time to react to prevent stranding of the vessel, collision or striking other obstacles.

In order to be safe when anchoring or using certain specific facilities at sea, the sailors, i.e. persons holding the required sailing licenses, should consider several factors relating to location, particularly protection from wind, waves, ocean currents, tidal streams and the like. On the other hand, planners and management of local/regional communities want to optimise the space at sea from the point of view of design and use of space, and should take into account a number of factors that will allow them to plan space according to the highest standards, taking into account a whole range of other factors, especially those related to nature, marine and coastal protection, the environment, traffic and technical conditions, the current situation on the ground, and so on. It is therefore a matter of finding a compromise between the desires of future users of nautical anchorages: the professional sailors and recreational boaters and the future concessionaires of nautical anchorages, spatial planners, administrations of local communities and other entities. This creates a very complex system of interconnections and interdependencies as the goal is to select the best places designated for the anchoring of vessels and to take advantage of all the benefits that these locations can offer in order to meet all or most of the users' expectations, while, on the other hand, striving to preserve the marine and coastal environment. The study of former goals and the related issues are in the focus of this dissertation.

The proposal for a systematic solution of the problem thus raised was realised by applying the methods of multi-criteria analysis. In this way, by using several (4) methods of multi-criteria analysis and decision making, the best locations of nautical anchorages in Split-Dalmatia County (of the Republic of Croatia) are determined. The methods of MCA are applied considering several conflicting criteria and the viewpoints of a large number of stakeholders. This process is carried out primarily with the aim of meeting the conditions related to the following criteria: safety of navigation, hydrometeorological, spatial, economic, and environmental criteria, both from the standpoint of future users and from the standpoint of spatial planners and the county administration. Considering the fact that previous research both in Croatia and worldwide has shown that there is no unified methodology for selecting the best locations for nautical anchorages, or for their design, especially from the point of view of navigation and the safety of vessels and life, this doctoral thesis makes both a professional – engineering and a scientific contribution.

The subject of this research is nautical mooring sites in the SDC area, for which a conceptual and systematic framework for their selection as the best locations is offered through the application of MCA. The selection of the best location for nautical moorings implies such nautical anchorages that are sufficiently safe from the effects of weather conditions such as wind, waves, tides, sea currents, etc., whose operation does not interfere with the surrounding maritime traffic, and that have minimal impact on the environment. Research and analysis primarily provide a framework for determining where to place the anchorage within a particular sea area, mostly in natural shelters and bays.

Anchorage planning must take into account a number of nautical, hydrometeorological, spatial, economic, environmental, operational and physical factors that affect the location, size, appearance and use of anchorages.

An overview of the factors affecting anchorage site is presented, and it is demonstrated that proper site selection and construction of the necessary facilities have a major impact on the safety of people, vessels and the marine environment. Within a range of possible locations (86), the best (25) locations for nautical anchorages are selected using MCA.

The syntagm "*nautical mooring*" implies a mooring location with buoys, so the term "*nautical anchorage*" used in the rest of the thesis refers to the nautical anchorage fitted with buoys. The focus of the present research is on nautical anchorages, while anchorages for ports open to public traffic are not the subject of interest.

The goal of the research is to develop a conceptual and systematic model for nautical anchorage selection based on MCA in Split-Dalmatia County and elsewhere.

The research will include the ways and methods used in MCDM and heuristics.

In this dissertation, the main research question is formulated with the following hypothesis:

H_0: It is possible to determine the most appropriate nautical anchorage by using the methods of MCA.

The auxiliary hypotheses are as follows:

H_1: In determining the optimal or most suitable locations for nautical anchorages, several factors and criteria must be considered, the most important being the following: safety of navigation, hydrometeorological, spatial, economic, and environmental aspects.

H_2: Applied MCA methods should give the same or similar results.

H_3: With the use of MCA, it is possible to rank mooring fields within the same site, not only the location (cove).

H_4: By using the expert analysis, it is possible to confirm the results of the ranking of the fields.

H_5: The values of the weight coefficients may be assigned so as to give priority to the elements considered most important by both users and future concessionaires.

1.2. Methodology and research plan

The conduct of the research includes reviewing previously available research, collecting and processing data based on a questionnaire designed to survey anchor site users, collecting a large amount of data using Geographic Information System (GIS) on potential anchor sites in the m area, and processing, storing, and analysing the data collected over the period of the last four years. Hence this dissertation is based on many years of field work, experience and good knowledge of the area, i.e. the opportunities, safety of navigation and development plans in SDC.

GIS is a system for managing spatial data and associated attributes. In a narrow sense, it is a computer system capable of integrating, storing, processing, analysing, and displaying geographic information.

In addition to the analysis and research of previous domestic and foreign sources and scientific research in the field of MCDM and the methods of MCA, this dissertation examines, processes and analyses the data collected in the period from September 2022 to mid-January 2023 in order to determine the best spatial locations with regard to maritime affairs, spatial planning and nautical tourism. The survey research refers to the collection of evaluations and attitudes of both recreational boaters and professional sailors in the field of nautical activities and maritime safety. The 74 respondents who completed the questionnaire and evaluated a set of most important aspects regarding the safety of navigation, hydrometeorological, spatial, economic and environmental factors, enabled the application of the MCA methods as well as the establishment of the most important criteria and their weighting values in the second part of the research, all with the aim of selecting the best locations for nautical anchorages in the SDC area.

By applying four methods of MCA: 1. AHP (*Analytic Hierarchy Process*); 2. TOPSIS (*The Technique for Order of Preference by Similarity to Ideal Solution*); 3. hybrid AHP-TOPSIS - 2N method combining AHP and TOPSIS method with double normalisation of input data; and 4. PROMETHEE II (*Preference Ranking Organization METHOD for Enrichment*) over the collected data, the main criteria are defined and their weights are determined, reducing the number of possible sites from 86 to 25 best ones.

At the very end of the dissertation, the obtained solutions are verified by comparing the results with the previously known expectations of the users, participants and interested parties.

The validation of the conceptual framework for the selection of nautical anchorages is done by applying expert analysis methods, i.e. using MCA methods and comparing the obtained results, analysing the points of view of the various stakeholders, comparing the baseline data with the obtained results and the expectations of the stakeholders with the proposed solutions for the selection of the best locations for nautical anchorages. This is done using functions and procedures of the programming package R.[1]

The scientific literature and other sources proposed for this dissertation research topic (determining the best locations for nautical anchorages based on MCA) is relatively scarce. While there is research on the application of Multi-Criteria Analysis (MCA) methods in spatial planning, such as for nautical tourism ports or spatially distributed data processing, and even for anchorage planning [2,3], these studies often focus solely on area selection without considering the specific requirements of each domain and the systematic correlation between selected criteria, especially those related to navigation safety. Some research only consider a limited number of criteria, locations, MCA methods, or use a single perspective, depending on the specific goal being investigated for spatial location selection. In this regard, the preparation of this dissertation presents a particular challenge to the researcher, especially with respect to: 1. The parallel application of multiple MCA methods; 2. The use of numerous input data (86 sites); 3. The application of multiple MCA methods combining many different criteria, i.e. Safety in terms of safety of vessels and people on them, hydrometeorological, spatial, economic and environmental criteria; 4. Selection of the best locations of nautical anchorages, both from the user's point of view and from the standpoint of the concessionaires, i.e. future investors; 5. Extension of the scientific methodology in terms of the research subject.

The analysis of the previous research, the review of the professional and expert literature, the analysis of the opinions of professionals and non-professionals in the fields of safety of navigation, navigation and maritime transport, spatial planning, environmental protection, etc., have shown the possibility of gaining new knowledge and continuing the research in the field where, until now, some criteria and aspects have not been taken into account when optimising the selection of the best locations for nautical anchorages.

In the research and analysis of parameters within the defined problem of determining the locations for nautical anchorages, several scientific methods are used, the most important being the MCDM methods. In preparation for the application of the MCA methods, the main factors influencing the selection of the best locations for nautical moorings are analysed in detail.

MCA provides a more reasonable and scientific path to the decision support in process of selection of a nautical anchorage than other methods of operational research and optimisation. The decision on the selection of the best location is the result of a comparison of one or more alternatives with respect to several criteria relevant to the solution, i.e. the selection of the best solution for the defined problem. Multi-criteria evaluation is primarily concerned with how information from a group of possible criteria can be combined into a unique evaluation index. Therefore, MCA can contribute to a more effective selection considering numerous, usually conflicting, criteria.

The research consists of two phases.

The first phase of the dissertation is based on a questionnaire. The attitudes and opinions of users of nautical anchorages and their requirements for the conditions they believe should be met by future locations for nautical anchorages are investigated. Five groups of criteria are analysed and evaluated: safety of navigation, hydrometeorological, spatial, economic, and environmental criteria. Based on the results of the survey, the second phase of the dissertation uses four different methods of MCA, considering ten criteria with AHP and AHP-TOPSIS-2N, and seventeen most important criteria with TOPSIS and PROMETHEE II to select the best twenty-five anchorage locations out of eighty-six possible sites. The twenty-five sites were selected because this number would meet SDC's nautical anchorage needs.

The parameters for the MCA were determined using the factor criteria. The main factors, i.e. criteria are: 1. field area; 2. area of the bay; 3. percentage of field area to area of the bay; 4. degree of protection/exposure to wind and waves; 5. distance from the coast; 6. number of anchorages in the same bay; 7. presence of shipping traffic; 8. official anchorages; 9. presence of submarine cables and pipelines; 10. Risk of collision; 11. Depth; 12. Degree of sea change and presence of ocean currents; 13. Proximity to public ports; 14. Proximity to existing anchorages; 15. Environmental elements (Natura 2000 environmental network); 16. Damage caused by anchoring the vessel to the seabed; and 17. Archaeological sites.

In selecting and analysing sites for nautical anchorages, all the existing and planned anchorages in the SDC area were analysed.

The analysis methods of GIS were used to look at the entire SDC area in order to use the elimination method, reducing the sites that do not meet the most important condition for determining a nautical anchorage site, namely anchoring safety. Sites with incomplete input data are not analysed either. Multiple decision criteria analysis (MCDA) associated with GIS filters out potential sites by evaluating factors, i.e. the criteria that ensure minimum conditions are met to be considered as potential sites for nautical moorings. The criteria for MCDM methods aim to determine the minimum conditions that each analysed site must meet.

The analysis and selection of the best sites by evaluation according to the defined, i.e. selected criteria are carried out using different methods of MCDM and heuristics as the main scientific methods.

The analysis is limited and performed according to a limited number of criteria. MCA is based on the evaluation of defined criteria according to the recognised and accepted rules, which are assigned certain weighting values based on the determination of their importance and impact. The selected criteria are unique and coherent, although some are interrelated and interdependent. Some criteria are of greater influence and importance, which is why they have been highlighted. This is true, for example, for the criteria determined by a boundary, distance to the coast, depth of the sea, etc., or for the criteria imposed by legal regulations, and the like. Therefore, certain conditions for the application of MCA methods have been established to ensure an appropriate problem-solving tool that defines and uses the specific elements and characteristics listed below:

1. the research is adapted to MCA methods;
2. MCA methods work with mixed data and allow the inclusion of qualitative and quantitative information;
3. the research directly involves, respects, considers and analyses the situation and the research problem from different points of view, provided by experts and other stakeholders and interest groups;
4. the research conducted is transparent, replicable, and accessible to all participants;
5. MCA methods include mechanisms to solicit feedback on the consistency of the decisions made.

The investigation is carried out on the basis of the input data, the selected criteria to which the objective and the values are assigned, using four methods of multi-criteria analysis that have different initial settings, all with the aim of being able to compare the solutions obtained, namely: 1. AHP; 2. TOPSIS: 3. hybrid AHP-TOPSIS -2N method combining AHP and TOPSIS method with double normalisation of input data; and 4. PROMETHEE II. All methods are implemented with the aid of the programming language R (version 4.2.2) and heuristics.

In addition to the above methods of MCA and heuristics, the dissertation applies general research methods used in the preparation of scientific and professional studies, namely: inductive and deductive methods, methods of observation and description, analysis and synthesis, classification and comparison, generalisation, specialisation, compilation, and others.

The R language, on the other hand, forms a free software environment for statistical calculations and graphics. It can be compiled and runs on a variety of UNIX platforms, Windows and macOS. The latest R version 4.2.2 (One Push-Up) was released on 2022-31-10.[1]

The dissertation develops a new conceptual framework and approach, which consists of assigning certain values and objectives of criteria based on the prior knowledge of the doctoral candidate, analysing the evaluations of the most important factors of nautical anchorages from the point of view of direct users, i.e. sailors, and obtaining information on the fulfilment of certain expectations. The information was collected by processing a questionnaire provided to visitors to ports and anchorages for nautical tourism in the SDC area and to the international community at large. It was also published on the pages of the International Association of Maritime Universities,[4] which evaluates the safety of navigation, hydrometeorological, spatial, economic, environmental and other factors in the area of nautical anchorages for navigation. This approach provided a more reliable, accurate, and equitable selection of the best locations for nautical moorings and provided a unique and important scientific contribution to the research field for the interested parties and academic community.

For the sake of better understanding, the interpretation and presentation of the final results is done in tabular and graphical form using the tools and functions of MS Excel (MS Office, 2019).[5]

1.3. Content and scientific contribution

The dissertation is divided into eight Chapters.

The first chapter contains an introduction that defines the problem, topic, objective, hypotheses, research methodology and scientific contribution. It reviews the main previous research related to MCA in the field of maritime and maritime security, spatial planning, and nautical tourism.

The second chapter defines and explains the basic characteristics and types of moorings and highlights the importance of nautical moorings in the field of maritime safety, navigation, nautical tourism, and the economy of the state and society.

The third chapter analyses the most important factors of nautical moorings, and the fourth part provides an overview of the current status of nautical moorings in the SDC area, as well as an overview of the most important factors and recommendations for selecting the best locations for nautical moorings.

In the fifth chapter, the input and the possible variants (86), the procedure for the selection of the criteria, their values, weights and objectives are described in more detail and the algorithms and phases of each applied method of MCA for ranking of mooring field, are briefly explained, namely 1. AHP, 2. TOPSIS, 3. Hybrid with double normalisation AHP-TOPSIS -2N and 4. PROMETHEE II.

In the sixth part of this thesis, based on the obtained input data and the application of the MCA methods, the results are presented and interpreted. This chapter also presents the best evaluated alternatives, the ratio and consistency index and other elements that confirm the quality of the selected alternative solutions, as well as a documented validation and comparison of the obtained results.

The seventh chapter of the dissertation contains plans for further research.

The eighth chapter comprises the main conclusions and explains the degree of confirmation of the hypotheses established in the introductory part of the thesis. Appendix A features the code in the R language for each MCA method used, Appendix B contains the survey questionnaire, while Appendix C provides detailed results of the survey research. The input and output data, as well as the order of significance and the order from the best to the worst result, together with the quotients and consistency indices, are stored separately for each method used, in matrix form in the ".*xlsx*" spreadsheet format in Excel, for ease of access and review. This chapter also features the part comparing the results obtained with different methods.

Scientific Contribution - The scientific contribution of the dissertation is manifold. The conceptual and systematic framework for the selection of nautical anchorages plays an important role in the process of spatial planning under the condition that all criteria related to the safety of the nautical anchorage are met. By applying MCA based on criteria assessments, it is possible to establish the basic principle of qualitative decision making in the process of determining the best sites for establishing nautical anchorages.

Therefore, scientific contributions involve: the application of unique expert analysis, the determination of systematic relationships between criteria, the classification of fields rather than just areas, the comparison of multiple MCA methods to obtain more credible results, and the unique validation of these results. The information obtained, the selected locations of nautical anchorages, can be used for various deeper and wider researches by professional sailors and recreational boaters, spatial planners, future concessionaires, county offices, scientific and professional staff and all interested entities, including the scientific and educational institutions.

In a systematic, clear, and verified manner, this dissertation provides a decision support system based on MCDM that helps all interested parties and analysts to decide, document, and describe, in a more effective way, complicated decision processes while selecting the best locations for nautical anchorages in a desired area.

This dissertation confirms that the methods of MCA are an extremely valuable tool for analysts and interested parties in the transparency and completeness of the description, transferability of the research design based on the presentation of the procedure for the optimal selection of construction sites / setting of nautical moorings. Therefore, it can also ensure coherent and consistent communication between different stakeholders in the field of maritime safety, navigation, spatial planning, and several of other disciplines.

The results obtained with this approach are useful and applicable in a whole range of fields, such as maritime safety, navigation, selective spatial planning, solving environmental problems related to the sea and the coast, etc.

In addition, the application of MCDM methods is comprehensively presented by providing a documented description of the MCDM methods used, using an accessible dictionary describing each step that must be taken to reach the selection results, providing a range of useful information on possible future locations for nautical moorings, linking the flow of procedures and data to a database of multi-criteria methods and the selection of appropriate criteria, and using and documenting the sequence of review and decision procedures.

It is expected that the results of this dissertation will enable knowledge transfer to other interested participants and analysts in the decision-making process in the field of maritime and shipping-related economic activity, spatial planning, marine and coastal environment protection and beyond. In this case, the process of MCDM methods will be operationalised and can be considered as a tool for training and educating analysts and researchers with less experience in such processes. They can first learn the components and steps necessary to conduct and follow MCA methods, guaranteeing a quality description of each step and criteria determination, resulting in an informed and documented selection of the appropriate MCDM method(s).

This dissertation offers recommendations for various methods of applying MCDM that may not perfectly fit the conditions of future case studies in selecting the best locations for nautical anchorages, but it can serve as a guideline for interested individuals who may use it as a manual in the process of their research and facilitate the process of monitoring the phases of MCA methods.

This dissertation also proposes a strategy for improving and acquiring new knowledge to guide and assist those who ask new questions and seek answers. Certainly, by reducing the set of available options in an efficient way, the MCDM methods that are described here may help those interested in making decisions and selecting methods and criteria.

1.4. Previous research

Previous research in Croatia and around the world has shown that there is no unified methodology for selecting the best locations for nautical anchorages, neither for their design, especially from the viewpoint of safety. Previous research has tended to focus on economic factors when selecting anchorages and included other aspects such as tourism[6], legal[7], social[8], sustainable development[9], and marine environment protection factors, while safety factors were mostly not considered in the selection criteria or analysed in a limited way [2], [10], [3]. The importance of selecting anchorages is reflected in the analysis of the basic concept of safety in navigation as an important and indispensable part of spatial planning. On December 29, 2022, the Croatian Ministry of the Sea, Transport, and Infrastructure adopted the draft of amendments to the Law on Maritime Domain and Seaports, in which, according to experts, the term "*anchorage*" is not correctly defined, and its operational function is defined as *"waiting for embarkation or disembarkation in port, i.e. mooring of ships to installed anchoring systems"*.[11] It was necessary to comply with the clear methodological and nontechnical rules for drafting legislation in order to define more precisely all the terms that define and specify the terminology of anchorages.

The choice of location is one of the most fundamental and important decisions when starting, expanding, or relocating any type of business. Based on the fulfilment criteria established in the business strategy, the process of site selection begins with the identification of the existing or anticipated needs to satisfy a new or growing market, and the need to initiate a series of activities targeted to the geographic area and specific location.

Choosing a site in any area, including spatial planning, and selecting the best locations for nautical anchorages, is a complicated analysis that brings together a number of important factors such as economic, social, technical, environmental, political, and so on. Clearly, many factors and actors need to be involved in the decision-making process, which makes the problem challenging, and selecting the appropriate tools to solve the problem allows for the concentration of data, information, and knowledge.

New trends in information technology are placing geoinformatics at the centre of what is happening in the science of places in space. A GIS is a system that creates, manages, analyses, and maps all kinds of spatial data by linking them to a map and integrating location data with all kinds of descriptive information, helping users to understand patterns, relationships, and geographic relationships. Like any current technology, GIS accurately describes and defines the spatial elements and highlights the advantages and latent disadvantages of information technologies, but in this time of technological development, the system used in the selection of sites for nautical anchorages is irreplaceable because it enables decisions based on multiple criteria based on spatio-temporal data. GIS enables data entry, storage, mapping, and spatial analysis of spatial attributes and data required in the process of supporting selection and decision-making activities.[12]

GIS is used together with other systems and methods such as expert systems (ES - *Expert System*), decision support systems (DSS - *Decision Support System*) and MCDM. The determination or selection of the best locations for nautical anchorages is determined by a set of criteria that must be met. In order to accomplish the task set, it is necessary to create a series of maps, each having a different theme, on which the degree of fulfilment of certain criteria can be determined.

So far, several attempts have been made in Croatia and in the world to combine and apply the above methods in order to find the easiest and most effective way to select the best spatial locations for certain purposes or to carry out certain activities.

The doctoral dissertation of M. Kovačić[13] contains a comprehensive analysis of nautical tourism and nautical tourism ports, as well as a detailed and systematic analysis of nautical tourism around the world. By comparing the nautical tourist ports in Europe, the facilities of Croatian nautical tourist ports were analysed according to their technical-technological structure and supply. Through the analysis of the quality of Croatia's nautical tourism, the objectives of the development of the port system and nautical tourism were determined by creating conditions for the optimal and efficient functioning of the system and achieving the maximum positive economic and social effect, with special attention paid to the environment. General and individual criteria for the selection of ports for nautical tourism were defined with the help of MCDM PROMETHEE I and II, GAIA (*Geometrical Analysis For Interactive Aid*) and AHP. By defining the criteria, the most important factors for the development of the ports of nautical tourism were determined, namely: normative, spatial, infrastructural, technological, economic, environmental, as well as the structure of human resources as an important factor for the sustainable development of a port of nautical tourism.

A model created and presented in the doctoral dissertation of M. Jurić[14] uses the MCDM to monitor the impact of each criterion on the marine environment AND establishes the criteria for evaluating the potential impact of LNG (*liquefied natural gas*) terminal functionality and operations on the marine environment.

Exclusion criteria were established to reduce, i.e. limit the considered space from which the representative sites were selected based on the previous evaluation of specific criteria. The observed problems were solved by the following methods: GIS MCDM (PROMETHEE and GAIA) and ES, and by using mathematical models and a regional model of the entire marine system as tools.

The research carried out in the dissertation of D. Schiozzi[15] refers to the search for an optimal model with five scenarios and the implementation of certain measures for the development of provincial and municipal ports in relation to the complementarity of the spatial concept of the port and city. The main indicators and measures that affect the level of spatial planning of the port and city were used to define and build the model. The success of the defined model was tested and demonstrated on the example of the Port of Rovinj.

The research of L. Krpan[16] refers to the analysis of the basic aspects of spatial, traffic, and transportation planning as a prerequisite for the preparation of spatial planning documents. The research points out the need to prepare transport strategies and studies as a basis for the preparation of strategic spatial plans like state, county, spatial plans of areas with special characteristics, and spatial plans of municipalities. Planning as a basis for the elaboration of lower-level plans (general and detailed urban plans) is analysed only in principle. The aim of the study is to provide scientific facts as a basis for the elaboration of a suitable conceptual land transport model.

Based on MCA, the study published by L. Maglić, P. Varaždinac and I. Škiljan[17] identifies potential locations for the construction of marinas at three places in Croatia's northern

Adriatic: Rab Island, Kačjak (Dramalj), and Voz (Krk Island). An MCA was performed based on five groups of criteria and fourteen sub-criteria using the PROMETHEE and GAIA methods. The assessment of the weighting of the criteria and the evaluation were carried out by interviewing a group of experts. A MCDM was prepared using the program VISUAL PROMETHEE. With the help of the PROMETHEE and GAIA, the Island of Rab was selected as the most suitable location for the marina.

The research performed by P. Badurina-Tomić et al.[18] analyses five possible sites for the selection of a suitable location for nautical tourist ports in Lika-Senj County. Using the MCDM and the software program VISUAL PROMETHEE, 1-Novalja (Island of Pag) was selected as the most suitable site. The contribution of this study consists mainly of a detailed analysis of the previous work and a proposal for possible measures for the further development of nautical tourism in Lika-Senj County.

The study carried out by L. C. Nguyen and T. Notteboom[19] presents a conceptual framework for incorporating multiple criteria into the evaluation of a dry port for developing countries from a multi-stakeholder perspective. The framework of the paper is presented in four steps covered by preliminary research, namely: 1. Stakeholders are grouped; 2. Sub-criteria related to the location of the dry port are listed; 3. Individual criteria and sub-criteria are explained; and 4. MCA is conducted.

The research[20] examines the logistical capabilities of offshore wind farms, specifically the physical characteristics, connections, and appearance of the port supporting the installation, operation, and maintenance phases of offshore wind farm projects. The relative importance of these criteria was determined using the AHP method. The AHP method is then applied as a decision support tool in a case study to enable decision makers to assess the suitability of a number of ports for offshore wind farms in the UK North Sea.

The paper[21] demonstrates the applicability of a spatial analysis based on MCDM methods to obtain accurate wind estimates at suitable sites for the offshore wind industry in the Red Sea. The study identifies three suitable areas with high wind resources and minimal constraints that can generate about 33 GW of energy. The methodology developed in the cited study can be generalised and applied worldwide in providing maps of the suitability of offshore wind farms at suitable locations.

G. Dapueto et al. also deal with the offshore wind energy. Their paper[22] presents a spatial multiple assessment (SMCE) aimed at identifying, at a regional level, suitable areas for the establishment of medium-sized fish farms on the coast of the Ligurian Sea. The SMCE process follows an integrated approach that can potentially be adapted and applied to any coastal system. The selection of sites is based on the definition of criteria to evaluate their suitability and on the conditions that apply to the entire study area. The results show that the SMCE process allows the identification of the most suitable areas and solves the complicated problem of spatial selection of a suitable site in a simple, fast and efficient way.

In their study[23], L. Gavériaux et al. present a methodological framework for identifying the most suitable marine areas for offshore wind farm construction in Hong Kong Bay. The method is based on the combined use of MCDA and GIS methods. The selection process is divided into two phases. In the first, unsuitable areas for offshore wind farm construction are identified, while in the second, the acceptable offshore wind farm areas are ranked using MCDA and different scenarios. Finally, a cost analysis was performed, and a comparison was made with the results of previous studies in this area.

The objective of the research[24] is to develop a strategy for the development of a flexible tool for the efficient installation of a marine energy park in a suitable area. The methodology used is based on a combination of GIS and MCDM methods and an optimisation algorithm. Three main criteria are used for the final selection of a site for a marine energy park, including the total cost of the project, the amount of energy generated, and the degree of social acceptability. The criteria of the degree of social acceptability are evaluated by the MCDM method ELECTRE III (*ELimination Et Choice Translating Reality*), while the optimisation of energy costs is approximated by a genetic algorithm. The whole approach is illustrated by a case study carried out in a maritime area in the northwest of France.

The study[2] focuses on integrating multi-criteria and stakeholder analysis into a modelling approach that assists land use planning professionals in developing plans for small vessel berths. The research focuses on an integral, sustainable approach to maritime spatial planning by modelling the concept for decision support processes to identify, validate, compare, and select sites for berth construction based on the multi-criteria method, goal analysis, and the logical decision support system. The paper used two methods of MCA in order to select best location from several small vessel berths respecting social, technical, economic, natural protection and cultural heritage factors. The concept was tested on the Island of Šolta in Croatia and proved to be an applicable, consistent, and efficient method for planning mooring sites.

The scientific paper[10] published by L. Butowski presents a research project based on mathematical and psychological principles and methods that combine AHP and PROMETHEE. The project develops an evaluation structure for assessing European coastal and offshore areas for nautical tourism. In a case study, a three-step evaluation structure is defined and tested. The results show that the method, which combines AHP-PROMETHEE, can be a useful tool for assessing the attractiveness of different destinations. It can also be used for practical purposes, in particular to identify the strengths and weaknesses as well as the competitive position of certain coastal areas compared to others.

This study[25] examines the potential of GIS -based MCDM in selecting a suitable and new area for oyster aquaculture. It includes a group of evaluation criteria that are measurable indicators of the extent to which the decision has achieved its objectives. The classification of GIS and the MCDM analysis have shown that this approach and method can be used to systematically find new sites for oyster aquaculture. This paper proposes to improve the appropriate spatial domain by using appropriate data parameters and advanced techniques.

The study carried out by N. Račić et al.[26] is a technical basis for amendments, i.e. for the adoption of a new Split-Dalmatia County (SDC) spatial plan. Possible future locations of nautical berths in the County are defined, based on navigational and meteorological aspects, technical-technological and traffic characteristics, maritime safety measures, Habitats Directive Natura 2000[27], the Register of Strictly Protected Species, technical-technological types of berths and organisation of berths by expert analysis. The cited study also describes the requirements that the investor must meet in order to obtain the necessary permits and papers to start the operations.

The research project[3] serves as a technical basis and support for the authorities of SDC and the Public Institute of Urban Planning in planning the future development and location of ports and anchorages for nautical tourism. The cited project considers the development opportunities of harbours for nautical tourism in SDC from the standpoints of optimal use and environmental protection. All elements of supply and demand in nautical tourism were identified through the SWOT analysis (*S-strengths, W-weaknesses, O-opportunities, T-threats*). By defining the advantages, disadvantages, strengths, and weaknesses of Croatian nautical tourism, it is possible to determine its strategy and direction of development. The application of the MCDM methods (AHP, PROMETHEE and GAIA) and for the ports of nautical tourism in SDC included a systematic study of the proposed micro-locations, which led to the selection of mainland and island sites. The next step was to define the criteria and sub-criteria for their acceptability. Finally, a qualitative and quantitative assessment of each proposed site was conducted.

The study[28] provides a scientific and technical basis for specific legal and technical solutions for ports of refuge for boats and ships in distress. The study established plans for solving the problem of ports of refuge, according to which every protected bay, harbour, and stretch of coastline is considered a potential port of refuge, regardless of the size and type of a vessel. The study analysed the state of maritime traffic in the Adriatic, especially along the eastern coast. An overview of the features of the coastline was given, and possible measures in case of a maritime accident or other emergencies or threats to the safety of vessels or the environment were evaluated. The cited study provides an overview of the procedures applied in supporting vessels in the navigation process, a description and presentation of the main features of possible shelters, in accordance with the existing experience and guidelines of IMO (*International Maritime Organization*) and EU (*European Union*) regulations. The study presents the design of a complete computer system for decision-making based on MCA in case of acceptance or recommendation to place a vessel in a port of refuge. Beyond the already established project objectives, the Boat Shelter Study identified the need to adopt and implement the proposed methodology and full computer support concept presented in the above-mentioned pilot project. The concept is based on the need to minimise subjective judgments in the decision-making process.

The report[29] provides guidelines and recommendations for the design of vertical and horizontal dimensions of access channels to the harbour, the selection of manoeuvring and anchorage areas within the harbour, and the establishment of restrictions on operations within the channel, including guidelines for establishing requirements and conditions related to the depth and width of the channel and the proposed vertical spacing of bridges.

The study of scientific and professional literature and data thematically dealing with nautical anchorages, criteria, and selection of new sites, especially in Croatia, shows that there is a modest amount of officially accurately collected data on their condition, registered physical traffic in organised nautical anchorages, especially in SDC. Moreover, the level of quality of services provided there is low, so it is necessary to use more modern analytical decision-making methods to collect accurate and precise data in order to optimally, completely and systematically select the best locations of nautical anchorages based on the data thus obtained and using the methods and tools of MCA.

Previous research on the problem of determining the best locations for nautical moorings in Croatia has shown that there is no unified methodology, especially not the application of MCA methods, for selecting the best locations for nautical moorings and their distribution, especially from the viewpoint of safety.

Most studies focus only on economic factors when selecting links, while other aspects such as tourism, legal and social aspects, sustainable development, protection of the marine environment and safety factors are usually neglected when selecting the criteria. The importance of link selection is reflected in the analysis of the fundamental concept of safety of navigation as an important and indispensable component of spatial planning.

In the last decades, the number of MCA methods has been constantly growing,[30] so that it is currently a real challenge for the analysts and interested parties to choose the most appropriate tools. The question arising in the context of this research is: what is the most appropriate MCA method or approach for selecting the best locations for nautical anchorages? There are several complications in conducting MCA that are related to the exact definition of:

1. framework of the decision-making situation to be examined;[31]
2. creation and characterisation of the alternatives to be considered;[32]
3. development, identification and assessment of evaluation criteria;[33] and
4. selection of the MCA methods for selecting the best locations for nautical moorings.[34]

Typical spatial site analysis problems, characterised as highly complex and intensive, can be effectively solved by applying modelling techniques and MCA regardless of the complexity, number and type of data, with the goal of identifying the best alternatives.

The structural complexity of the maritime space, shipping and maritime security in general, and systems and relations with the environment, changes in demand in the tourist and nautical market, security conditions, characteristics of the maritime and tourist economy, economic conditions, working conditions, the environment and other influences determine the location of new sites, while the changes in the production of new forms of services, characteristics of the operation process, frequency of technological changes and the impact of disruptions in shipping and the maritime and tourist-nautical market require the adjustment of the existing spatial planning systems and the use of the maritime environment.

The construction of a new system of nautical moorings is a large and long-term investment. In this sense, the identification of new sites is a critical point on the road to the success or failure of the system to their use. One of the main objectives in selecting sites for nautical moorings is to find the most suitable site that meets the desired conditions defined by the selection criteria.

In selecting sites for nautical moorings, an attempt is made to optimise the number of targets in determining the suitability of a particular site for a particular system. Many, sometimes conflicting, factors often come into play in such optimisation. Several important factors contribute to the complexity of selecting the right sites, including the fact that there are numerous possible locations.

A number of complicated critical factors are involved in the siting of nautical anchorages, including maritime, spatial, hydrometeorological, traffic, technical, economic, social and other issues, marine environment protection issues, etc. The complexity of the process requires the simultaneous use of multiple decision support tools, such as ES, GIS and MCDM. In the past, the choice of location of nautical anchorages was based almost exclusively on the economic and technical criteria. Today, a higher standard is expected, so selection criteria must meet a range of spatial, safety, traffic, environmental, nautical, social, and other requirements, sometimes mandated by regulations or legislation.

Risk management in the selection of new anchorages for concessions is a truly critical factor in the success or failure of spatial planners, the managing authorities involved in the process, and other interested parties, who should be familiar with the stages of the process for selecting the best site.

Anchor concessions are granted in accordance with the Croatian Law on Maritime Domain and Seaports,[35] the site permit, i.e. the spatial planning documents, and the Regulation on the Procedure for Granting Concessions on Maritime Property.[36]

The initiative to start the procedure is taken by a private or legal entity after the border of the maritime domain has been determined and entered in the cadastre and land registers.

If the concession includes the implementation of the encroachment on the area of maritime property, the procedure for granting the site permit, i.e. the procedure for the preparation and adoption of a detailed development plan, is initiated by the Administrative Department of Tourism and Maritime Affairs of SDC. If there is a legal interest, the administrative department of tourism and maritime affairs may, by resolution, authorise the applicant for the concession initiative to obtain a site permit in the name and on behalf of the grantor.[37]

One of the most important and far-reaching decisions that operations managers face is determining the best locations for nautical anchorages.

Information gathering allows the generation of potential locations for nautical shelters, which can be grouped in several iterations according to specific conceptual criteria to gradually narrow down the choices. In this way, only certain sites are selected from the total number of the available ones because only a certain number of sites meet all the relevant criteria. Finally, the decision makers make a final decision that may still be in conflict with the sites proposed by the method or the computer program.

Gathering information about the best future sites based on selected criteria and evaluating their importance allows the decision maker, typically the state or municipality, to create a list of the best possible sites or shortlisted sites. From this group, the decision-makers, i.e. investors and/or concessionaires, select one or more sites based on the previously established criteria.

In contrast to previous research and studies, this dissertation proposes a systematic, comprehensive and documented tool that combines several approaches, including (1) a survey of future berth users, (2) several methods of MCA, and (3) different perspectives, i.e. (a) users-sailors, (b) planners, and (c) future concessionaires, by means of a creating, programming, and using pre-built or new functions and packages in the R language.

2. GENERAL TERMS, DEFINITIONS AND SIGNIFICANCE OF NAUTICAL ANCHORAGE MANAGEMENT

The purpose of this chapter is to define general terms and to explain the types and significance of nautical anchorages. Additionally, it emphasises the need to establish anchorages and manage them based on a number of factors, such as navigation safety, hydrometeorological, spatial, economic, environmental, operational, and social factors, as well as the importance of strategic guidelines when determining the sites and managing them in a sustainable way.

2.1. Basic characteristics of anchorages and their definitions

An anchorage is a place at sea where vessels can drop their anchor and stay for a while. In the era of sailing ships, anchorages were places to wait for the winds to blow, while these days, cruise ships typically anchor in a small port and passengers disembark on smaller boats.
There are several types of anchorages, including those with or without mooring equipment to keep a vessel in place. Anchorages with devices for securing the vessel in place are called ***moorings***. In this dissertation, however, the terms "*anchorage*" and "*mooring*" are used equally and interchangeably.
According to the Tomas Nautica Yachting Survey 2012,[38] organised anchorages attract sailors. Just knowing that there is an organised system for keeping the vessel in controlled conditions gives the crew a sense of safety.
Thus, an anchorage, which is similar to a mooring, is a place for vessels to moor and stay. The term "*anchorage*" is a maritime term meaning "*act of anchoring*" or "*anchorage charge*."[39]
Anchorage is also a geographical area suitable for anchoring vessels. It should ideally have a suitable sea bottom or substrate, be free from strong currents and significant sea level fluctuations, and be protected from waves and wind.
Anchorages are marked on nautical charts with a small black anchor symbol.[40]
An anchorage is also a place with sufficient depth of sea, river, or lake water where vessels are anchored within a port.[41]
"*A nautical anchorage is a part of the sea or water surface suitable for anchoring vessels equipped with devices for safe anchoring*." [42](art. 8)
The study is about determining optimal locations for "*short-term anch*oring", as there are rules in maritime economics that are used for "*long-term analysis*".

The term "*surface*" is also used in the rest of the paper, but “area” could be also used as a synonym referring to “*part of the water surface/area of the sea, the bay, the cove, part of the coast or the surface/area of the anchorage or its field”*.

An anchorage is, thus, a part of the water's surface designated for mooring vessels in a bay protected from bad weather. Safe anchorages are located in the water area of the port or bay, while open, i.e. unprotected anchorages are located in the unprotected water area and are intended for a shorter stays of ships, overnight or for several days.

Article 132 of the Spatial Plan of SDC[43] defines anchorage as “*a part of the sea area suitable for anchoring vessels equipped with devices for safe anchoring*.” *Anchorages are divided into three groups: 1. anchorages; 2. anchorages for ports open to public traffic; and 3. special purpose ports*.

Anchorage planning is carried out according to the above plan, together with the prior elaboration of the anchorage project based on the fulfilment of certain criteria. Thus, the anchorage project must take into account the possibility of planning the anchorage based on the nautical and meteorological-oceanographic characteristics of the water area, nature conservation criteria, and meet the criteria referring to the safety of navigation and the stay of vessels. Finally, the anchorage project must obtain the harbour master’s approval.

Anchorages must not be established in the areas designated as protected areas in nautical charts and official publications for navigation or in the areas where anchoring is prohibited.

The future areas of the anchorage cannot be planned in a way that interferes with maritime traffic safety. The anchorage project, therefore, requires determination of the anchorage's protective belt, area, and number of anchoring sites (devices or buoys).

Once an organised mooring is established within the ecological framework, further moorings outside the system are not allowed.

In contrast to nautical anchorages, anchorages in ports open to public traffic and in specialised ports such as shipyards, military and industrial ports, and ports serving state-owned enterprises are determined by the law establishing the port area.

Commercial anchorage is generally considered commercial when the owner does not moor his/her own vessel on the shore or in his/her own berth, but leases a portion of the water area to other users for short-term mooring, anchoring, and temporary use in exchange for financial compensation.

Often, these types of moorings are run by cities and marinas, which make them available to tourists for vacation rentals or for short-term commercial purposes.

Open anchorages are generally not equipped with commercial infrastructure. From a shipping perspective, private anchorages and anchorages for ports open to public traffic are identified by clear signs and need to be distinguished from those intended for vessels subject to the payment system.

2.2. Importance and economic impact of nautical anchorages

The choice of suitable locations for nautical anchorages is primarily an investment decision, as anchorages are often concessioned for a specific period of time.

The cost of establishing a nautical anchorage of a certain capacity and quality depends on the region's characteristics. If the natural conditions of the region are favourable, the decision to establish an anchorage is easier and cheaper. A suitable choice of location ensures lower installation and construction costs, better capacity utilisation, higher sales prices for nautical-tourism services, higher efficiency, and a faster return on investment, which is especially beneficial for concessionaires.

While planning the optimal location for an anchorage, the fundamental problem is that the spatial development plans are not in conflict with the development possibilities of the surrounding area.

Another issue is the lack of spatial plans that precisely and accurately regulate both the locations and conditions for establishing moorings, which frequently results in inadequate spatial solutions. The problems are usually more revealed in smaller or more densely inhabited areas, particularly when several moorings are planned on the sites, when anchorages do not exist although there is a significant need, or when they are not planned at nautically advantageous and less expensive locations, etc.

Any changes to the marine area must be coordinated with local city plans and land use plans for future development of the area.

The positive effects of the establishment of a nautical anchorage can be seen in the improvement of the supply at the general nautical-tourism level and, in particular, through a series of activities such as the provision of catering, hotel and other accommodation services, the possibility of renting boats, the development of other related activities, etc. All of this promotes the growth of the local community's income, the expansion of job creation, the improvement of the population's standard of life and the overall progress of the economy of the region and, eventually, the country.

Along with the benefits, the existence and use of marine anchorages have a negative impact on the environment. This is a result of inappropriate waste disposal methods, waste water discharged from vessels, waste oil discharged from fuel stations, improper disposal of solid waste, etc. Other negative impacts of the existence and operation of anchorages include: the loss of wildlife habitat due to the use of concrete, chains and other material, sea level changes and pollution, increased noise levels, lower light levels required for normal development and survival of marine life, etc.[44]

For the foregoing reasons, it is extremely important to determine the actual needs and potential risks before establishing nautical anchorages and determining their locations. When assessing the requirement for anchorages in particular areas, there are a variety of factors to consider. In order to achieve the desired outcome, it is typically necessary to strike a balance between maintaining the anchorage, port, or berth's effective operation, the safety of the vessels, their crew and passengers, as well as the conservation of the marine environment.

Significant and popular nautical destinations require a suitable system for accommodating nautical tourism vessels. In addition to marinas for nautical tourism and other specialised and non-specialised berths, mooring at an anchorage is a very common and popular method to ensure the safety of vessels, but also easier compared to anchoring in ports/marinas and other complicated mooring facilities.

The safe and efficient operation of a nautical anchorage often requires that vessels moored there wait for a suitable berth in the marina, i.e. the port of nautical tourism, or, as in the case of a port for public traffic, wait for the conditions to load or unload their cargo.

In these circumstances, vessels have several options that are available:

- with prior Notice of Arrival, the vessel may reduce its speed in order to reach the anchorage or port at a suitable moment;
- the vessel may decide to remain at the anchorage/berth in port until permission to enter freely is granted;
- the vessel may drop anchor at a nautical anchorage, or
- any combination of the above conditions.

There are a number of reasons why a ship or the person operating the ship may choose to anchor rather than sail or float. These reasons are as follows:

- for the leisure and recreation of the passengers and/or crew or to reduce ongoing fuel costs;
- to reduce the crew workload;
- to perform maintenance on the vessel;
- to reduce or limit the impact on other users of the waterways;
- reasons for conducting port activities such as transferring passengers and/or crew from one vessel to another; and
- uncertainty of embarkation time/schedule of passengers and crew, etc.

Each of these reasons should be weighed against the potential negative impacts on vessels calling at the anchorage, which include:

- the risk of damage to submarine cables, pipelines, and other facilities;
- impact to the seabed and biodiversity by dropping the anchor and retrieving the cable;
- discharge of pollutants/waste from vessels or harmful gas emissions;
- impairment or alteration of the coastal panorama's aesthetic value;
- impeding access by other users to resources within the World Heritage Area;
- disturbance and negative impact on marine organisms and species depending on the conservation of these organisms;
- in the case of larger commercial vessels, because of the possibility of marine pests being introduced onto the vessels, etc.[45]

Buoys for mooring at nautical anchorages should be placed in a well-defined area that is at a safe distance from shore and provides adequate space for the intended vessels. They should also provide protection from the open sea and wind and should not impede the passage of other vessels. In addition to the above criteria, nautical anchorages must be environmentally sound. Since some of the above criteria are in conflict with each other, a compromise solution must always be found in the final selection of nautical anchorages.

The anchorages in SPC are located in the central part of the eastern Adriatic coast, recognised as one of the most exclusive nautical destinations in the Adriatic Sea.[46]

The vessel arrival system is confirmed by the vessel's position in the queue. For larger merchant ships, this period can range from one to two weeks prior to arrival. Therefore, port and anchorage managers should evaluate all relevant factors when considering the implementation of a marine anchorage management plan. For nautical anchorages, the waiting time for the assignment of an anchorage is short (a few minutes).[45]

As a result of increasingly stringent and demanding regulations to protect the marine environment and coastal landscape, as well as due to requirements for comprehensive coastal management and sustainable development of nautical tourism, any new project in a sensitive coastal area is subject to rigorous review by a wide range of procedural stakeholders. Accordingly, the development of new infrastructural facilities for nautical tourism is often questioned.[47]

The management of anchorages in Croatia is the responsibility of the regional administration in accordance with the laws and regulations applicable to the territory,[35,36,48] and includes the granting of concessions and supervision of nautical anchorages, on the basis of which part of the maritime domain is excluded from public use and awarded to an authorised concessionaire.

The economic impact of nautical anchorage concessions is reflected in the financial results and in the increase in employment of the local population in the areas where the anchorages are located.[49,50,51]

The direct financial effects of granting a concession on maritime domain are: fixed concession fee and variable concession fee for the duration of the concession contract.[52]

The indirect financial effects of granting a concession include the income tax, contributions from employees' salaries and VAT.

The significant positive socio-economic impacts of organised anchorages on the local community and beyond pose challenges for impact assessment, monitoring, control, and management of marine, underwater, and coastal protection. The presence of an anchorage becomes an integral part of the management of the coastal area, reducing "*illegal anchoring*" and uncontrolled dumping of waste into the sea, increasing the safety of navigation and complementing the tourist supply and experience.

Organised anchorages protect the environment by properly disposing of waste. The construction of new anchorages ought to be considered as an important component of nautical tourism that supports the social and economic growth and development of the coastal area. Moreover, it is a form of supply that, unlike marinas, involves simpler forms of service provision that focus on the safety of sailors and their vessels.

Operators of anchorages, i.e. investors (especially concessionaires), are always interested in the highest possible utilisation of the anchorages, i.e. in a larger number of vessels, because they can achieve higher financial revenues, although the number of vessels is inversely proportional to the safety of the vessels at the anchorages and is accompanied by an increased risk of possible environmental damage, etc.

In most cases, there are no specific criteria for determining anchorages, but there are relevant recommendations,[53] good maritime practice, and guidelines, most of which relate to larger vessels and anchorage techniques in general. [29,45,54,55]

According to PIANC,[29] the anchorage design depends mainly on the following factors:

- the dimensions, the construction and the characteristics of the vessel;
- the type of activities the vessel will undertake at the mooring;
- the duration of the vessel's stay;
- the overall configuration and availability of the berth manoeuvring area;
- the general organisation of moorings and/or fixed anchorages;
- the number of fixed anchoring sites at the anchorage;
- the distance from the coast;
- the marine environment condition in the area of the anchorage and the limiting

operational conditions;

- the physical characteristics of the location, particularly the depth, shape, and structure of the seabed on which the anchor is located;
- the availability of resources and agencies responsible for marine pollution prevention and control, etc.

Sites selected for nautical anchorages must be large enough to allow vessels to move free of obstructions. Bathymetry is a branch of oceanography that measures and analyses the depths of a sea, lake, or river. Based on the depth measurement, bathymetric maps are created on which the bottom relief can be determined using isobaths. Bathymetric maps are commonly made in shades of blue, which changes from lighter tones at shallower depths to duller tones as depths increase. This means that the bathymetry should be relatively flat and devoid of obstacles, far from busy waterways, etc. The anchorage should be selected so that it has a suitable natural or man-made marker to indicate the vessel's accurate and safe position as it approaches and remains in the anchorage. The turning radius or swing circle of the anchored vessel should also be analysed, along with elements indicating the possibility of inaccuracies at the anchorage, the length of the vessel, the length of the chain and/or ropes under load of horizontal projections, the influence of tides, and the safe distance from the movement of other vessels. The safety distance may be set, for example, at 10% of the vessel's length and at least 20 m, except for fishing vessels and pleasure craft, for which it may be reduced to 5 m.[29,56] The length of the mooring buoy chain should be about 1.5 of the maximum depth. (Figure 1) The distance between vessels in mooring systems with multiple buoys should not be less than the width of the largest vessel + 1.0~2.0 meters.[56,57]

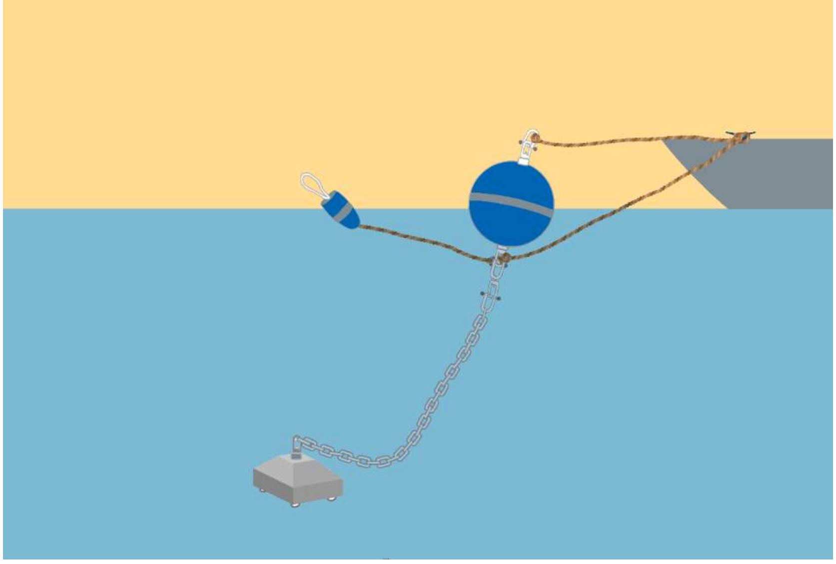


Figure 1. Mooring on an anchored buoy

Source: [Author]

Under Keel Clearance (UKC) of 10% draft may be acceptable for a protected site or near a protected harbour.

Guidelines for mooring design and management[29] as key elements for mooring design are:

- location of the mooring (degree of protection from wind and waves, depth, projected area, weather conditions, appearance and infrastructure of the mooring, other users of the waterway, proximity to populated areas, connection with coastal facilities, etc.);
- size and layout of berths (use of a combination of berthing radius adapted to anticipated vessel sizes, resulting in a smaller overall berthing area;
- anticipated extent of berth use;
- environmental considerations (environmental impact assessment, extent of seabed disturbance from anchor dropping and chain retrieval, management of emissions, pollutants or wastes, aesthetic values, introduction of marine pests, local cultural heritage values, etc.).

In the plans of anchorages in space and other plans, buoy fields and anchorages are generally represented by simple geometric shapes such as circle, parallelogram, rhombus, rectangle, etc., while anchorages for smaller vessels may be indicated by irregular geometric shapes, depending on the coastline and the size of the available water area.

Even though Croatia's nautical tourism industry is not yet one of the major contributors to marine and coastal pollution, the ever-increasing number of vessels and the tendency for accommodating larger boats more frequently increase the amount of generated waste (both biodegradable and non-biodegradable), which needs to be collected and properly treated.

The management of anchorages in Croatia is the responsibility of the regional administration in accordance with the laws and regulations applicable to the territory,[48,49,51] and includes the granting of concessions and supervision of nautical anchorages, on the basis of which part of the maritime domain is excluded from public use and awarded to an authorised concessionaire.

The location, size and maximum capacity of the anchorages shall be determined by the SDPMC (*Spatial Development Plans of Municipalities and Cities*) based on the previously prepared "*SDC Anchorage Layout Plan*", which shall be prepared and adopted based on the Spatial Development Plan and the "*Study of SDC Anchorages*".[37]

The aforementioned study includes an analysis of navigational, meteorological, technical-technological, traffic and navigation characteristics and maritime safety measures, a map of the habitats of the Natura 2000 ecological network, as well as the organisation and the technical-technological methods of anchoring.

The establishment of SDC anchorages is planned by the SDPMC and forms the basis for granting concessions for the use of maritime resources.[43]

The fee for anchoring in Croatia depends on the location and organisation of anchoring and is additionally regulated by law.[58] If dry waste (garbage) has been removed, the concessionaire is required to issue a certificate of removal of waste from the vessel. Dry waste removal is included in the fee. The person operating the vessel, boat or yacht is obliged to keep the receipt(s) on board until the vessel leaves the territorial waters of the Republic of Croatia. Upon the boater's request, the concession holder is obliged to present a price list of mooring fees certified by the County Office.

3. THE KEY ELEMENTS OF A NAUTICAL ANCHORAGE

3.1. Anchorage sites

There are several factors to consider when identifying suitable sites for anchoring vessels. These factors will often require consultation with a wide range of stakeholders. Below are the most pertinent guidelines and recommendations for factors to consider.

3.1.1. Sea depth

Anchorages must be of sufficient water depth for a vessel to operate safely, but not so deep as to render anchoring ineffective. Considering that the anchors are connected to the vessel by means of an anchor chain or, in the case of smaller vessels, by an anchor rope, the limitation is the length of the *anchor line*. *Anchor line* and *anchor cable* are general terms that refer to a line of any material suitable for anchoring.

The *anchor line* on large merchant ships usually varies depending on the size of the vessel and the depth of the sea at which the vessel is anchored. In general, it is recommended that the anchor line be at least three times the sea depth at the anchoring point in fair weather. If the depth is high, anchoring is unsafe. This is because it does not depend on the anchor itself, but also on the type and length of the anchor line at the bottom.

A space below the keel of a vessel of 10% draft is considered the ideal proportion for sheltered anchorage locations or a sheltered port. However, for multiple anchorages in open water, the vessel's keel spacing may need to be increased to allow heeling while at anchor.[29]

Due to the fact that the depth indicated on nautical charts may sometimes be inaccurate or unreliable, it is essential to determine accurate and precise depth data for anchorage areas.

Official navigation maps give the user an indication of the quality of the displayed depth data in the form of *Zone of Confidence* (ZOC), as shown in Table 1.

Table 1. Zone of Confidence

Zone of Confidence	Position Accuracy	Depth Precision	Seabed coverage
A1	+ 5m	= 0.5m + 1%d	All significant seafloor features detected
A2	+ 20m	= 1.00m + 2%d	All significant seafloor features detected

B	+ 50m	= 1.00m + 2%d	Unchartered features hazardous to surface navigation are not expected (but may exist)
C	+ 500m	= 2.00m + 5%d	Depth anomalies may be expected
D	Worse than C confidence zone category	Worse than C confidence zone category	Large anomalies may be expected
U	Unassessed - The quality of the bathymetric data needs to be assessed		

Source: [45]

Table 2 shows possible risks in the establishment and management of anchorages, as well as possible strategies for reducing and managing these risks.

Table 2. Possible risks in the establishment and management of anchorages

Key risks for the mooring	Establishment	Management	Mitigation strategies
Location	X	X	Ship and port operations Jurisdiction approval Safe water depth Good holding ground Adverse weather allowance Efficient anchorage layout Design for variety of uses Minimise effect on port and infrastructure Minimise conflict with other waterway users
Seabed disturbance	X	X	Avoid or reduce need for anchorage Design for reduced impact footprint Allocate anchorages to minimise impact Minimise time at anchorage
Survival of plant and	X	X	Management of vessel activities Minimise time at anchorage

animal species			Aggregated anchorages Avoid sensitive habitat areas
Aesthetics	X		Consideration of visual impact when designing anchorages
Marine pests		X	Aggregated anchorages IMO ballast water controls Ship inspections Marine pest monitoring Minimise time at anchorage
Discharge of pollutants		X	Port State Control inspection Management of ship activities Provision of port waste services Minimise time at anchorage

Source: [45]

3.1.2. Holding ground

In favourable conditions, the anchor line weight on the seabed is generally sufficient to keep the vessel in position. However, in adverse weather conditions, a stronger "*penetration*" of the anchor into the holding ground is required to prevent the vessel from drifting out of position. The physical composition of the anchorage holding ground is crucial for ensuring safe and effective anchorage. Anchor must be buried in the holding ground so that the anchor line can be laid across the bottom. This provides effective vessel safety.

Ideally, the anchoring site should be relatively flat and free of natural or man-made obstacles, allowing the anchor line to extend in a straight line and the anchor *to hook* well to the bottom. The tide, currents and wind will cause anchored vessels to turn around their anchors. As the vessel rocks, the anchor line will drag along the holding ground, so it is imperative that the anchorage is clear of obstructions.

It is important to examine both the type of bottom and obstacles in the anchorage area before creating a nautical anchorage plan.

A holding ground composed of silt or sand or sand/shells provides an excellent holding ground, as the anchor can be easily *embedded* in the seabed.

The quality of the anchorage holding ground can be evaluated as follows:

- Mud - good;
- Sand - good;

- Gravel - medium;
- Shells - medium;
- Compacted sand - bad;
- Stone - bad.[29]

Holding ground material consisting of rocks and compacted sand is considered a rather poor holding ground. Anchors often fail to keep the vessel in place in extreme weather conditions, particularly in strong currents and wind. Generally speaking, holding grounds are also susceptible to major damage to anchor lines. They often provide a platform for algae and other parasites to get caught. As such, these types of seabeds should be avoided.

If the seabed does not provide adequate holding capacity, alternative anchorages in other locations should be further considered.

3.1.3. Meteorological and hydrographic factors

Wind, possible storms, currents, and tidal variations will have to be considered to ensure the safest possible anchorage.

Anchorages exposed to high winds and/or heavy seas will affect the vessel's ability to safely manoeuvre to and from the anchorage. In addition, it will affect the anchor's ability to hold the vessel in place. In more exposed locations, larger anchorage areas may be required to accommodate the additional anchor chain to be laid. This is due to the increased potential for vessels to drag their anchors.

For ship-to-ship passenger and crew transfer activities, time will be critical. Anchorages exposed to strong winds and/or open seas will limit the amount of time available for a safe transfer.

3.1.4. Layout and infrastructure of the anchorage

Anchorage locations will need to be located so that they do not encroach on existing waterways, including keeping channel approaches clear. However, they will still be allowed safe passage from the waterway to/from the anchorage and port.

Anchorages should be kept away from the current and future planned traffic and other infrastructure, such as gas or water pipelines, submarine electric and telecommunication cables, tunnels or overhead power lines and bridges.

A vessel's anchor can act like a plow, and any infrastructure on the seabed will suffer significant damage if a vessel's anchor passes over it.

Regardless of how secure the holding ground is, vessels occasionally drag anchor. In order to give the captains or skippers of vessels ample time to react in the event of a related issue, anchorages should be placed clear enough of the potential hazards. The anchorage should not be located near critical structures on the shore which could endanger the floating vessels.
It is customary for anchorages to have a system of secure and efficient communication transmission with/at shoreside amenities such as port services for vessel traffic (VTS - *Vessel Traffic Services*), which necessitates that anchorages be accessible by marine VHF radio and other communication links.

3.2. Size and arrangement of anchorages

The size and layout of the anchorage are largely determined by the anticipated number, size, and type of vessels expected to use it.
Under the same weather, wind, and tide conditions, vessels having different sizes, drafts, hull shapes, etc., behave in different ways. Therefore, it is important to consider the vessel's sway angle in relation to nearby vessels when choosing an anchorage. Due to the probability of vessels swaying in different directions rather than simultaneously, this is done to effectively prevent collisions at sea.
PIANC,[29] for example, provides helpful guidance on how to determine the size of individual anchor fields and their placement. These calculations generally result in a dummy space, an anchor circle of a certain radius, based on the size of the vessel anchored approximately in the centre. They include allowances to extend the length of the anchor chain installed based on the prevailing sea depth, weather conditions, vessel length, and safety limits.
The anchorage area may contain individual anchorages with various turning radii to accommodate vessels of different sizes and hull shapes.
Smaller ships may securely anchor in shallower waters, which necessitates the deployment of less anchor lines. In contrast, larger vessels will require deeper waters to anchor safely, resulting in more anchor cables to deploy. By using combinations of different sizes of false spaces that correspond to the expected size of the vessel, a smaller overall footprint of the anchorage area and more efficient utility can be achieved.
The number of individual anchorage positions is determined by the expected frequency of use as well as the time spent at the anchorage.
There are several factors that indicate the required number of anchorage positions and the expected anchoring time. This includes the use of the port, the number of users, and the management of arrivals and departures at the port.

Unfavourable weather conditions can further worsen the situation, so in such cases, it may be necessary to include additional anchorages or foresee that the vessels anchor outside the anchorages.

When anchoring outside the marked mooring area is not acceptable, it is necessary to formally consider alternatives to anchoring. This is an alternative anchoring, mooring or floating of the vessel.

After determining the size of the individual anchorages, the next decision relates to the number of anchorage fields. The question is whether the same bay will have one general-purpose or more separate anchorage fields.

General anchorage is chosen when the number of vessels expected to anchor at any given time is low, there is sufficient free space and environmental protection, and care are not given much importance.

3.3. Anchorage management

3.3.1. Allocation of anchorage

When implementing a marine anchorage management plan, port and anchorage operators should consider all relevant factors.[45]

As a result of consistently stricter and more demanding regulations on the protection of the marine environment and coastal landscape, as well as following the requirements of comprehensive management of the coastal area and sustainable development of nautical tourism, every new operation in a sensitive coastal area is subject to strict assessments by a number of process participants. Accordingly, the development of new infrastructure and facilities for nautical tourism is often questioned.[47]

Installation of buoys in a certain area reduces the degree of influence of potential adverse effects of vessels on the ecosystem. That's mainly because the concessionaires and the harbour masters now have more control and authority over the anchorages. On the other hand, the seabed and marine biodiversity quickly recover from the negative impact of anchoring on the holding ground.

Likewise, it was determined that the more frequent and intensive use of a smaller number of anchorages has less negative impact on the environment than if the number of anchorages is increased. So, by applying the anchorage allocation regime, concessionaires can guide vessels to alternative anchorages, ensuring that all anchorages are utilised equally and preventing safety from being compromised by the number of vessels, thus further minimising the detrimental effects of anchoring on the holding ground.

3.3.2. Anchorage and communication regulations

In general, anchorages in ports open to public traffic are used mainly by vessels calling at the port to load or unload cargo. However, the design of nautical anchorages can mainly depend on other elements, on which the design of anchorages in ports open to public traffic are not particularly important. Vessels in the ports open to public traffic use the anchorage for more than just recreational and leisure purposes. For instance, vessels may stay at the anchorage as a result of bad weather conditions, crew and passenger transfer from the vessel to shore, and vice versa. As a result, there are fewer losses and transitional delays for the crew and passengers.

As anchorage for the port open for the public traffic, nautical anchorage is used for a variety of purposes and is usually a place at sea where a vessel can stay:

- for protection from bad weather, wind, waves, etc.;
- for rest and recreation of the passengers and crew;
- as a safe place to carry out repair or maintenance work on the vessel;
- for carrying crew members, change spare parts; or
- for providing emergency medical care to passengers.[45]

However, nautical anchorages, unlike anchorages in ports open to the public traffic, are mostly used for recreation and entertainment.

The entities responsible for managing the anchorage must establish rules for the effective operation of the anchorage and determine the form and communication requirements.

Entities responsible for managing nautical anchorages should have plans and procedures for transmitting and receiving information about vessels entering, transiting, or leaving the nautical anchorage.

The information may include, but is not limited to, the following requirements: information - notification of vessel arrival and departure times, safety and weather information, special traffic warnings, etc.

The authorised concessionaire shall be responsible for maintaining order at regulated anchorages in accordance with the concession agreement, while the person operating the vessel shall be responsible for the vessel's safety at the anchorage and shall comply with the instructions of the concessionaire and the harbour master in charge.

When the vessel is at anchor, the person operating the vessel shall ensure that the vessel has sufficient clearance from the nearest vessels. The clearance should be appropriate in all directions and in all weather conditions. When the vessel is at anchor, it shall display signals and lights during the day in accordance with the "*International Regulations for Preventing Collisions at Sea*".[59]

3.3.3. Discharge of pollutants or waste from ships

Nautical anchorages, as well as anchorages in ports open to public traffic, should have comprehensive policies prohibiting the discharge of solid and liquid waste. In addition, they should have measures to limit greenhouse gas emissions while vessels are at anchor. At the same time, relevant international and national laws on discharges from vessels should be followed.Measures that allow vessels access to waste disposal facilities, limit laytime, and facilitate active management reduce the risk of discharges during laytime..[60]

3.3.4. Activities of vessels at anchor

While lying at anchor, vessels often use the time for onboard activities such as lifeboat drills, overboard maintenance, engine repairs, and even fishing. Establishing a management regime for these vessel activities beyond normal operations will reduce potential negative impacts. It is recommended that the following activities be managed:

- Fishing from boats may not be allowed in certain areas due to local fishing regulations or in marine protected areas such as nature parks;
- Potential engine repairs will depend on the exposure of the anchorage to anticipated adverse weather conditions, the quality of the anchorage, and the time required for repairs. In general, clearance for engine repairs should not be given when inclement weather threatens;
- Approval of abandoned vessel drills using life-saving equipment - boats or rafts - depends on port and anchorage regulations, sea state and local currents, and expected weather conditions;
- All authorised work depends on the expected weather conditions and the measures taken to ensure that no pollutants and materials are released into the marine environment.

3.3.5. Reducing the risk of anchoring due to collision, impact or stranding of the vessel

According to the IMO, "*risk is a measure of the probability that an undesirable event will occur. It is also associated with a set of consequences that will occur in real time*."[61]

Reducing the risk of accidents while a vessel is anchored due to a collision, impact, or grounding of the vessel includes a number of preventative measures that can be taken to reduce the risk of such events.

A collision is a situation or incident in which two or more vessels come into contact with each other. This causes damage or potential danger to the vessels and crew. Indirect collision refers to a situation where there has been no actual contact between the vessels. Instead, there has been a violation of the rules for avoiding collisions at sea or an error in manoeuvring. This has resulted in a *near-miss* rather than a collision. A passing vessel may cause a hazardous wake or wash resulting in problems for an anchored vessel, including damage to the interior, breaking the anchor line, man overboard, etc.

A vessel collision is a situation in which a vessel contacts a surface or object, such as the shore, another vessel, or the bottom. A grounded vessel is a situation in which the vessel's bottom touches the sea bottom or another obstacle. A distinction is made between accidental and intentional grounding when the ship's captain or the boat's skipper selects this option to prevent sinking. Sinking of a vessel as an undesirable consequence of a collision, impact, stranding, or another hazard such as fire, explosion, terrorist attack, etc. It occurs when the vessel partially or completely sinks to the bottom. Submergence in the sea and loss of vessel stability are also included in accidents or incidents resulting from a collision, impact, or another event.

Ports are usually located in or near populated areas, often resulting in competition between multiple parties for the use of the waterway. Equal access and use of the waterway and port land are significant factors in selecting appropriate anchorage locations.

Good anchorages are characterised by shallow, sandy, or muddy bottoms. Such anchorages are suitable for the marketing and cultivation of seafood such as fish, shellfish, and other molluscs. They are often suitable for commercial inshore or sport fishing, trawling, longline fishing, etc. Therefore, commercial and recreational fishing, fish and shellfish farming, underwater fishing, etc., should be considered when determining an anchorage location. A large number of boaters live and travel in populated areas and compete for the use of the waterways. They all use the waterways, interact with other vessels and users of the sea and shoreline, and have the same right to the access and use of anchorages.

Because anchorages for larger vessels are relatively large open areas with wide spacing between anchored vessels, there is generally no need to exclude other users of the waterways from this area, as vessels can pass unimpeded.

For safety reasons, it may be necessary to establish exclusion zones around certain anchored vessels. These vessels may include military vessels or vessels performing transfers from one vessel to another. The risk assessment must be made by observing the traffic at the anchorage, the type, number, and size of vessels, and by analysing the hydrometeorological factors at the anchorage. Based on all factors, individual scenarios must be defined for each risk.

3.3.6. Control and supervision of the anchorage

One of the core responsibilities of maritime safety is the preservation of the marine environment, as well as the protection of life and property at sea. One tactic to guarantee the accomplishment of these objectives is the control of government ports.[35]

One of the international conventions targeted by Port State Control (PSC) is the compliance with the International Convention for the Prevention of Pollution from Ships (MARPOL), the main international convention for the prevention of pollution from vessels.[62,63]

In cases of suspected pollution from anchorages, additional targeted on-site monitoring by the state monitoring authorities having the jurisdiction over the anchorage may be required to review the situation, identify the causal factors, and initiate action to address the problem.

Croatia conducts inspections according to international guidelines and within its powers. If the inspection reveals reasonable suspicion that the vessel and/or its equipment or crew do not comply with the relevant requirements of the international convention, a more thorough inspection and monitoring shall be carried out.[64]

3.3.7. Port services

According to the IMO conventions, vessels are obliged to manage waste generated on or in connection with the vessel. This is to prevent that ship's operation from having a harmful impact on the marine environment. Vessels implement these regulations by using incinerators, storage tanks, and environmentally sustainable discharges.

In ports and anchorages where vessels are expected to remain at anchorage or berth for a long time, a system of internal waste management can be organised. At anchorage locations, an appropriate group of port facilities and services can be provided that are located in the immediate vicinity of the anchorage. This will enable vessels to manage their own waste. This can be done through receiving facilities on shore or through contractors at sea who service anchored vessels.

According to the IMO Conventions, ships must manage waste generated on or in connection with the ship. This is to ensure that the ship and its operations do not adversely affect the marine environment. Ships implement these requirements through incinerators, storage tanks, and environmentally safe discharges.

In ports and at anchorages where vessels are expected to be at anchor for extended periods of time, a system of internal waste disposal may be established. At anchorages, an appropriate set of port facilities and services may be provided close to the anchorage. This will allow ships to dispose of their own waste. This can be done by receiving shore facilities or by contractors at sea whose duty is to care for the anchored vessels.
The daily operations of the port and vessels, as well as the purpose of anchorage, will affect the anchorage location.
For vessels arriving at port to load and/or unload cargo in port, the vessel may be required to provide a Notice of Readiness (NOR) upon arrival. Depending on the rules in a particular port, this may be within the prescribed port limits where the port authority has jurisdiction. It may also be within the territorial waters where the state has jurisdiction.
Service providers and regulators may need to access the vessel to perform certain operations. These operations may include customs activities, transfer of crew and/or passengers, and the like. Ideally, anchorages should be positioned and designed to ensure the highest level of vessel safety.
For emergency anchorages, the passage plan route through ports and anchorages identifies and marks the most suitable locations near the navigable channel/route.
Anchorages should be located in a specific area to allow regulatory control, such as within port boundaries or state waters.

3.3.8. Lost anchors

If the dropped anchor is lost within the anchorage limits, it is necessary to notify the other participants of maritime traffic as long as the retrieval process is in progress until it is completed. The notification should contain the approximate position and the measure of the safe distance from the vessel pulling out the anchor. It should also prohibit anchoring, fishing, swimming and diving, as well as other activities.
Lost anchors pose a safety risk to other vessels and fishing gear, especially trawl nets. At the same time, lost anchors, anchor chains and ropes, which are most often made of plastic materials, represent pollution of the sea. They must be removed as soon as possible to prevent further damage to the area.

3.3.9. Emergencies

While the vessels are at anchor, unexpected and sudden situations may occur, which concern a group of unexpected and unfortunate cases, injuries, collisions, medical problems with the

crew and passengers, fires, collisions, vessel damage, stranding, etc., which can lead to the injury or death of passengers on board or other people in the area.
Anchorage managers, concessionaires, and others are responsible for managing the nautical anchorage. For this reason, they should have established procedures and procedures in the event of an emergency. These procedures should be published and available to vessels intending to use the anchorage. Factors such as the number of vessels, the availability of anchored vessels, and the contact of local emergency services should be taken into account in the procedures. Through the procedures, it is necessary to work out a plan for the evacuation of the anchorage due to unexpected and sudden events, and the ways of implementing the evacuation. The plan must ensure that the users of the anchorage are aware of all of measures. Employees who take care of the anchorage should pay special attention to the weather conditions, e.g. to the approaching storm. Regardless of the fact that the anchorage may be good, protected and safe, they should inform the users about the change in weather conditions and advise them to increase attention and vigilance.

3.4. Environmental considerations

Proponents of new anchorage locations should seek to minimise the environmental and social impacts associated with the use of anchorages. In addition, they should maintain the efficient operation of anchorages and harbours in the immediate vicinity of anchorages.
There are a number of potential environmental issues to consider when assessing an anchorage site, many of which will be site-specific and can only be identified through a detailed assessment of environmental factors.
However, there are some key environmental factors that are consistent across locations.

3.4.1. Environmental assessment

There are numerous methodologies for assessing the possible environmental impacts of proposed anchorages.
Before undertaking an environmental impact assessment, proponents should investigate any previous environmental impact assessments or marine and subsea status determinations by the relevant regulatory agencies. It is worth examining this, as it may reduce the need for the significant investment of time and effort required for an environmental impact assessment.
For example, Marine Park development plans may have previously permitted anchoring in certain areas, negating the need for further environmental assessment.

3.4.2. Impacts on the seabed

The drag of the anchor and chain can create grooves across the seabed. Certain animal and plant species, their habitats or geological deposits can be destroyed in some marine areas. This can be avoided or reduced by limiting the need to anchor the vessel or by reducing the area affected by the anchor line.

Analyses of nautical anchorage design and location are aimed at minimising potential negative impacts on the environment and on the holding ground. This can be realised by minimising the anchoring area and anchor fields and defining anchor drop points to reduce the area of the holding ground that is negatively affected by anchoring. By reducing the footprint in the anchorage area, the extent of exposure to impacts on habitats is reduced.

Without the use of specific anchor points for vessels, there is a possibility of increased fragmentation of the holding ground. In addition, there is the possibility of adverse impacts occurring on a larger spatial footprint than was previously defined or allowed in the planning of anchor fields.[65]

For the above reasons, it is recommended to prioritise areas with lower biodiversity or areas of common and widespread biodiversity/habitat types. In these areas, the overall negative impact on marine life and habitats will be smaller.

Certainly, anchorages management requires a high level of knowledge and expertise in terms of logistics, organisation, efficiency and consistency in all segments and functioning activities.

3.4.3. Emissions, pollution and waste management

When planning anchorage locations, one should consider the availability, spatial distance, and speed of intervention of companies that deal with the services of correct and legally permitted collection of waste from vessels, in relation to the expected need for these services, as can be foreseen in the activity plan of these companies. The realisation of the activity will depend on the type of vessel and the time of anchorage. This will define the conditions for the methods of discharge of wastewater at anchorages and in their immediate vicinity.

Even though it is forbidden, people frequently discharge waste (faecal) water at anchorages. The installation of black tanks for excrement and wastewater on vessels is mandated by legislation, hence it would be required to design and establish the processes for collecting and discarding them.[35]

When planning the location of anchorages, one should take into account the proximity of ports that provide nautical services and the availability of safe collection, processing, and treatment of waste, as well as the availability of barges for waste and fuel when servicing vessels.

In general, waste, sewage, grey water, and oily waste can be held in a vessel. However, the size of the tank and storage space will determine the retention time.

3.4.4. Aesthetic factors

The presence of anchored vessels in the view from land and along the passageways of vessels can potentially reduce the visual aesthetics of the area of the site where the nautical anchorages are located. However, the effect on appearance is very subjective. The assumption is that most people associate nautical anchorages with shipping, nautical tourism and the sea, so it is to be expected to see vessels at sea, in the harbour, and/or at anchorages. Indeed, for many, the possibility of watching the vessels is an attraction.

Due to the size and draft of most vessels that require anchorages in the deep sea, anchorage locations are generally far offshore. This reduces the visual impact created by anchored vessels, especially if large vessels are considered.

The selection of adequate anchorage locations should definitely consider the effect the vessels have on the view aesthetics. Certainly, one should avoid anchoring in a place that degrades well-known and appreciated views.[66]

The ecological value of the micro-location of the nautical anchorage includes the appearance of the area where the nautical anchorage will be established and its integration with the visual quality of the space, marine and terrestrial communities, as well as the overall aesthetic appearance of the anchorage location.

When deciding on the location of an anchorage, an ecological component attracts more visitors to it. The stated conditions also apply to measures of protection, arrangement, and preservation of the environment and landscape of anchorage locations. Therefore, it is imperative to consider the ecological value of the micro-locations of nautical anchorages.

3.4.5. Marine pests

Vessels in transit between international ports can carry and introduce marine pests as fouling, within ballast water, or on the anchor and anchor chain itself. The International Maritime Organization's International Convention for the Control and Management of Ships' Ballast Water and Sediments, together with the accompanying national legislation, provides an effective framework for reducing the risk of marine pest infestation.[67]

Although anchorage design has little effect on preventing intrusions, regular and effective surveillance at anchorage sites can assist in early detection and, therefore, early problem-solving intervention.

3.4.6. Conservation-dependent species

Although vessels and marine species co-exist in and around ports and shipping routes, the extent to which marine transport disrupts marine species' behaviour remains unknown. However, it must be considered that the vessels sailing and anchoring may displace certain marine species from their habitat. Therefore, nautical anchorages near critical feeding or breeding habitats of protected species should be avoided.[68]

In terms of preserving protected species and geo-mechanical characteristics, the type of anchoring devices that have the least impact on jeopardizing the species should be determined based on the established features of the holding ground. Within the area of the ecological network, by implementing anchorages in the areas where the target habitats are spread, e.g. disruption of the priority target habitat type of Posidonia settlements (*Posidonion oceanicae*), it is important to use, instead of anchor concrete blocks, other technical solutions that minimally disturb the sea and biocenosis seabed using drilled anchoring systems, e.g. Helix type, Manta Ray, etc.

The impact of artificial lighting on certain species, such as sea turtle hatcheries, must be considered during the design phase and long-term management of the anchorage. Light pollution can disturb sea turtle hatchlings and confuse their navigation sense. When designing moorings, the proximity of moored vessels to the nesting area of the species should be taken into account. This is to ensure that the moored vessels are at a sufficient distance lest to cause disturbance.

Vessels at anchor and vessels underway generate noise as part of their normal navigational operations. Although not considered significant compared to noise from nearby port operations, vessel noise that interferes with marine species' behaviour remains unknown.

Implementing a management regime for navigational activities above normal operations will reduce the potential impact.

3.4.7. Local heritage values

Ports and coastal anchorages should have an established local heritage policy. Potential areas may have cultures with different social, cultural, and environmental values that need to be considered.

It is necessary to talk with local stakeholders about the impact of potential anchorages, in order to obtain a list and the status of all areas of importance.

Anchored vessels may disturb areas of special significance to local groups, including traditional owners of land adjacent to the areas and coastline where the anchorage is planned. Everything possible should be done to avoid activities that disrupt the "*normality*" of areas where local values of special importance have been identified.

4. EVALUATIONS OF CRITERIA FOR SELECTING NAUTICAL ANCHORAGE LOCATIONS

In this part of the dissertation, the results of the survey research representing the views and opinions of sailors are presented and analysed in detail.

The basic premise of any process is decision-making, so several decisions were considered in determining possible locations for nautical anchorages. At the strategic level of decision-making, after defining the area, the methodological approach and the problem, the first step is to define the objectives to be achieved. (Figure 2)

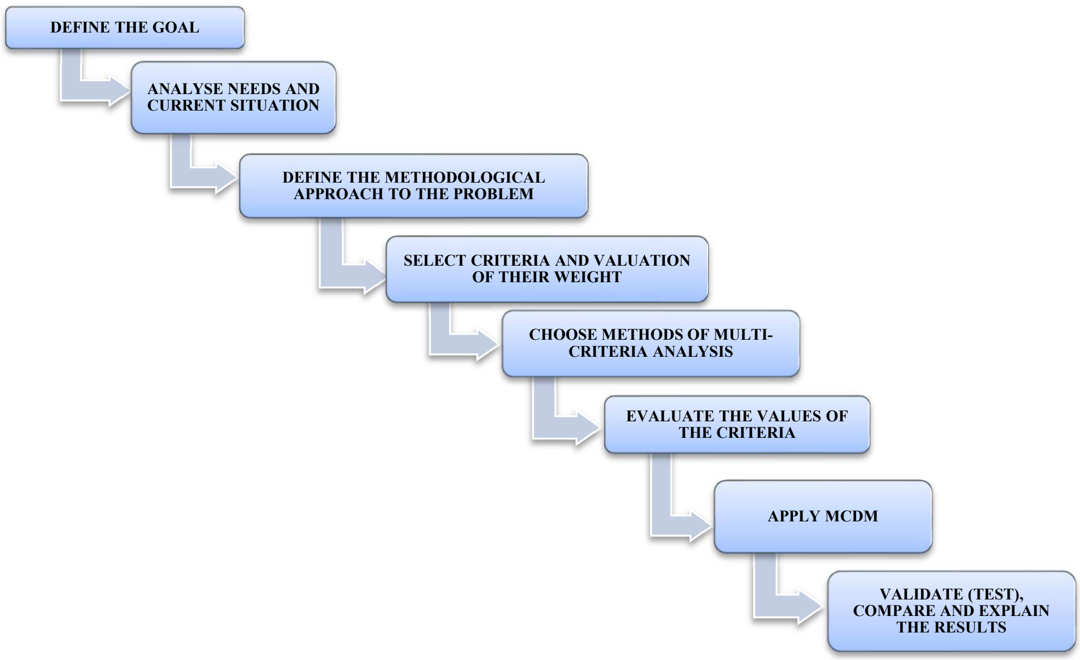


Figure 2. Choosing the best locations for nautical anchorages

Source: [Author]

This research applies MCDM to the selection of the most suitable locations for nautical moorings from the point of view of safety.

In order to achieve the stated objective of selecting the optimal locations for nautical moorings, numerous criteria are considered and all aspects are analysed from different perspectives.

Once the objectives are defined, the criteria must be established, including a set of possible solutions that allow a qualitative selection of optimal locations. The evaluation criteria result from the ranking of alternative solutions.

In the first part of the research, the opinions and viewpoints of future users of nautical anchorages are analysed.

The opinions were obtained through a questionnaire that included five groups of criteria: navigation safety, hydrometeorological, spatial, economic and environmental criteria. The questionnaire was created and sent electronically to the respondents via the ArcGis survey 123[69] web service between November 2022 and January 2023.

The survey questionnaire form is available at https://arcg.is/1brLHq, while the survey questionnaire results are available at https://arcg.is/yTaLD.

The questionnaire was completed by 74 respondents. Appendix B contains the questionnaire form with all the questions asked. The fourth chapter of the dissertation analyses in detail the results obtained and presents the scores obtained for each of the five groups of criteria: safety of navigation; hydrometeorological; spatial; economic; and environmental. Appendix C clearly presents the results, i.e. the respondents' answers and scores to all the questions.

Based on the results of the questionnaire, the objective of the first part of the study was to explore the opinions and views of the future users of the proposed nautical anchorages in the SDC area on the conditions they believe should be met in order for the nautical anchorages to function effectively according to all the criteria listed previously and for the users to feel safe.

In line with the review of the existing research, the established anchoring points, best practices and professional rules, the selection criteria can be divided into general and specific. The general anchorage criteria mostly relate to the specific safety aspects and benefits. Each choice of anchorage has certain safety aspects but also different convenience aspects, depending on what is required for navigation.

Safety aspects include:

- Sea depth;
- Influence of wind and waves;
- Type of seabed;
- Influence of currents;
- Protection of the bay and other criteria shown in Figure 3.

Specific criteria are used to determine the location according to needs and opportunities. For example, a crowd at a nautical anchorage will have different requirements than a secluded cove. A heavily trafficked area or an area with a relatively large number of residents will require careful anchoring to ensure a solid anchor hold. This will ensure a long stay at the anchorage.

- Coastal access is also a specific criterion for nautical anchorage. The anchorage should be large and secure, even if there are shallow waters in the immediate vicinity. Coastal access is not ideal for this type of anchorage, as any boat ride would be lengthy. This is especially true if there is no beach or pier in the immediate vicinity.

- Easy shopping and/or proximity to other services, restaurants, bars, etc.;
- Pet-friendly nautical anchorages;
- Cell phone services and/or WiFi, etc. There are also specific criteria to consider when anchoring in the open sea;
- Possibility of water and electric power supply.

The main criteria for selecting the most appropriate locations for nautical anchorages are divided into five groups to cover all the important features of an anchorage, including those related to the safety of navigation, influence of tides and sea currents, wind, space, and economy, as well as the features related to the environment. These criteria cover all the segments that are important from the standpoint of sailors and those who care about the environment, but also from the point of view of future users, i.e. concessionaires. (Figure 3)

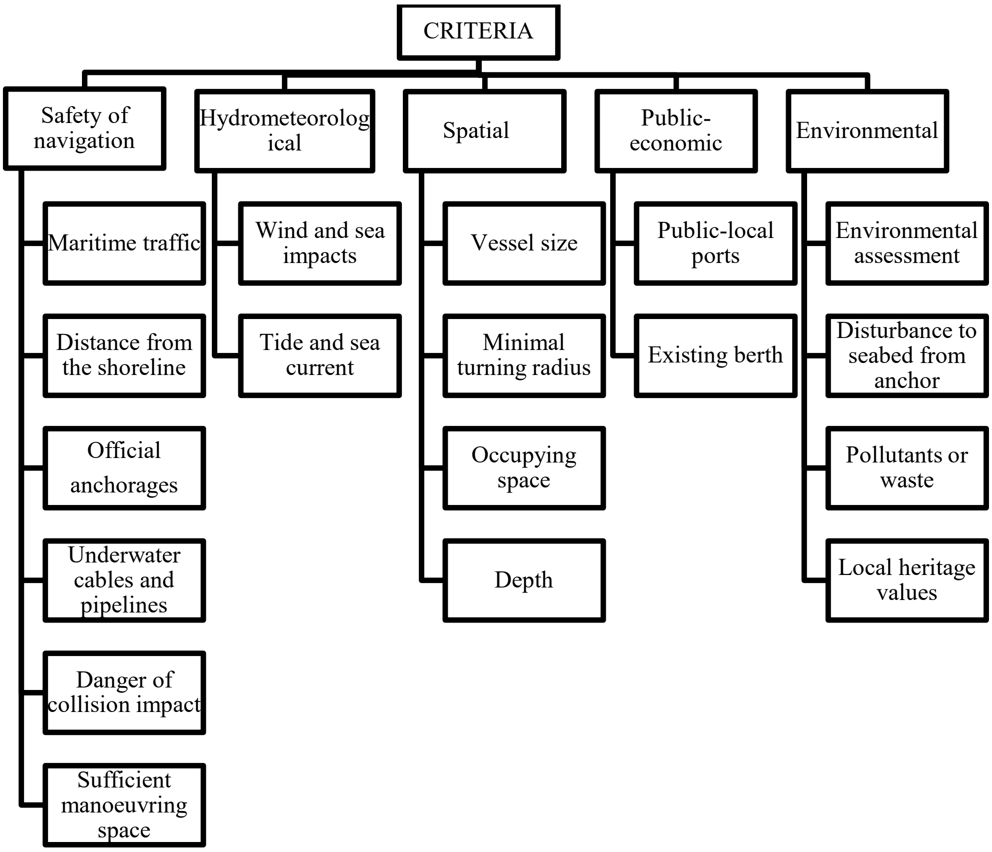


Figure 3. The most important criteria for nautical anchorages (space vs area)

Source: [46]

Thus, the safety criteria for navigation depend on:

- the existence and limits of the present state of maritime traffic in future locations;
- the distance from the coast;
- proximity to submarine cables, pipelines, and other facilities;

- potential hazards from collisions, impacts, groundings, and other hazards;
- space to manoeuvre to and from the anchorage.

Hydrometeorological criteria refer to:

- degree of protection of the bay or shore from waves and wind;
- the influence of sea currents and tides.

Spatial criteria refer to:

- size and length of the vessel;
- the required manoeuvring space and turning radius of the vessel;
- the occupancy of the entire anchorage by vessel; and
- the depth of water required for the vessel to enter safely.

Economic criteria refer to:

- the proximity of the port and the port area;
- the number of available public berths in the immediate vicinity of the anchorage;
- access to and distance from land;
- availability of transport and other infrastructure;
- price of berthing services for vessels.

The environmental criteria refer to:

- existence of marine or coastal protected areas;
- ways to reduce harmful effects on the environment;
- avoidance of disturbance of the seabed through moorings with drilling anchors and mooring devices that do not adversely affect the seabed;
- the possibility of reducing harmful effects on the environment; and
- the possibility of collecting pollutants or waste from the vessel and disposing of them

From the users' point of view, all the analysed criteria could be summarised as follows:

- avoid anchorages in the immediate vicinity of underwater cables, underwater installations, and other places where anchoring is prohibited;
- avoid setting up an anchoring field that would pose a potential danger of collision, impact, injury, and other dangers to people or vessels;
- mooring fields should not limit the manoeuvring space for vessels outside the anchorage field where they are manoeuvring, considering that sufficient space should be provided for vessels approaching and leaving the anchorage;
- anchorage fields should be in areas as protected as possible from the influence of bad hydrometeorological conditions, mainly from wind and waves;
- the anchorage fields should be in the area with the least impact of tides and sea currents;

- the anchorage area should be of sufficient depth, at a safe distance from the coast, as well as other installations and transit routes of other vessels;
- the area of the anchorage should be wide enough so that the turning radius does not cross the boundaries of the field or overlap with the swing radius of other vessels;
- anchorage fields should be avoided in the port area;
- moorings should not interfere with the existing public moorings;
- access from the mainland to the anchorage should be free of obstacles, and the moorings at the anchorage should be neither too close nor too far from traffic and other infrastructure;
- the expected occupancy of the anchorage field, from the point of view of the concessionaire, should be economically profitable;
- the negative impact of anchoring on the environment should be as small as possible;
- the negative impact of anchoring on the seabed could be reduced by using drilled anchors and anchoring equipment that does not disturb the seabed;
- pollutants or waste should be collected from the vessel and properly disposed of on land;
- local heritage values should be preserved as much as possible, etc.

From the point of view of other participants, those who plan and eventually decide on the selection of the best locations for nautical anchorages - although they may also be future users - the list of recommendations that must be analysed and evaluated is somewhat different and has different priorities.[37]

4.1. Data analysis from the perspective of the users of nautical anchorages

In this part of the doctoral dissertation, the results of the survey research, which represent the views and opinions of the users, are presented and analysed in detail. The data used as input in the research were collected in two ways.

The first was collected through survey research, while the second is the result of long-term data collection on nautical anchorages in Split-Dalmatia County (SDC).

In the first part of the research, which refers to the understanding of the real evaluations and preferences of the characteristics of nautical anchorages from the "*user's*" standpoint, the goal is to investigate the real expectations of sailors regarding the conditions met by nautical anchorages.

The answers were derived from the survey questionnaire. Data on ratings from the survey questionnaire represent the degree of importance of certain criteria in the opinion of users (sailors). The ratings represent the degree of importance of all criteria on which the sailors provided feedback for the survey.

The group of respondents was asked to evaluate the criteria using five-point Likert scales (Table 3) ranging from "*not necessary"* to "*very significant",* thus determining the weight of each individual criterion.

A Likert scale is a type of scale that represents attitudes and consists of a series of statements devoted to different aspects of attitudes. It is assigned to the respondent with the task of expressing the degree of agreement or disagreement for each individual statement, as a rule, on a five-point scale such as: "*I do not agree at all*", "*I do not agree*", "*I have no opinion*", "*I agree*", "*completely I agree*". Each respondent's answer is scored appropriately, and then by adding up the points for each statement, a total score is obtained that expresses the respondent's attitude, to a certain extent positive or negative towards the object of the attitude. It is suitable for factor analysis and is an advantage of this scale.

Table 3. Five-point Likert scale and its description

Scale	Importance weighting
1	Not necessary
2	Less important
3	Moderately important
4	Important
5	Very significant

Source: [70]

Hence, in the questionnaire, the users evaluate the factors they consider important, describing and evaluating the most significant ones that, in their opinion, "*should*" be met in order for nautical anchorages to be considered "*safe places for the stay, use and mooring of vessels*" in the area of the Croatian part of the Adriatic coast and, in particular, in the area of SDC. Based on the collected ratings of respondents from the survey, the most important criteria and ratings were selected so that in the second stage of the research procedure, before applying a specific MCDM method, certain weighting values could be assigned to each criterion based on the following criteria: the surface of the field, the surface of the bay, percentage of surface fields to the surface of the bay, protection/partial protection or unprotection of the bay, distance from the shoreline, and a number of fields.

The questionnaire was distributed at the beginning of September 2022, and it was available until January 2023. 74 respondents presented the answers.

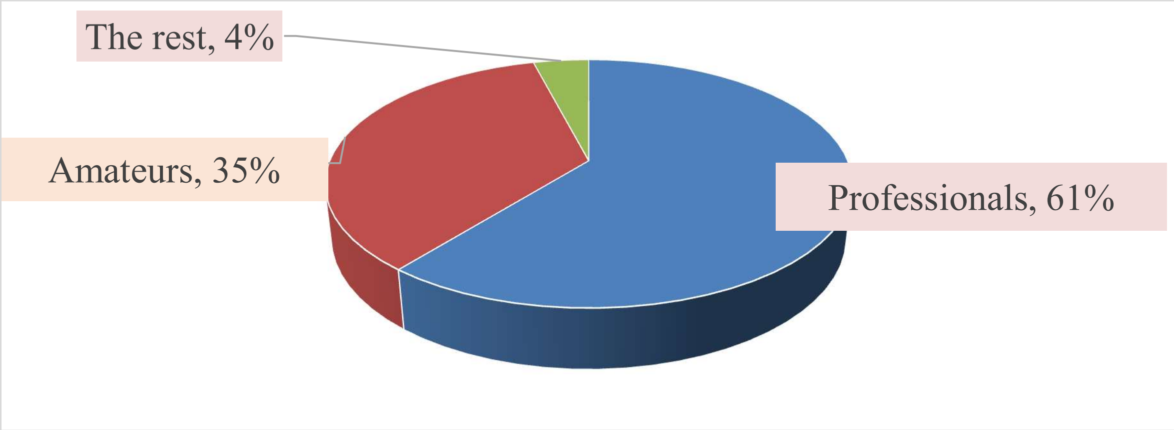


Chart 1. Structure of sailors

A total of 74 users evaluated the seventeen most significant factors of nautical anchorages in five groups. The distribution of respondents, with more professionals (61%) and fewer recreational boaters (35%), is shown in Chart 1.

Most of the surveyed sailors (36 and 50%, respectively) own a vessel with a length between 4 and 10.6 meters, and 11 of them own a vessel from 10.6 to 17.2 meters. Numerous respondents did not answer this question (22 and 31%, respectively), so it is assumed that they do not own boats, but instead use friends' boats or rent boats. (Chart 1)

The most of sailors surveyed (32 or 44%) own a motor-driven boat; 18 of them (25%) own a sailboat. A large group of respondents (22% or 31%) did not answer this question, confirming that respondents are likely to use rental boats, either motorboats or sailboats. (Chart 2)

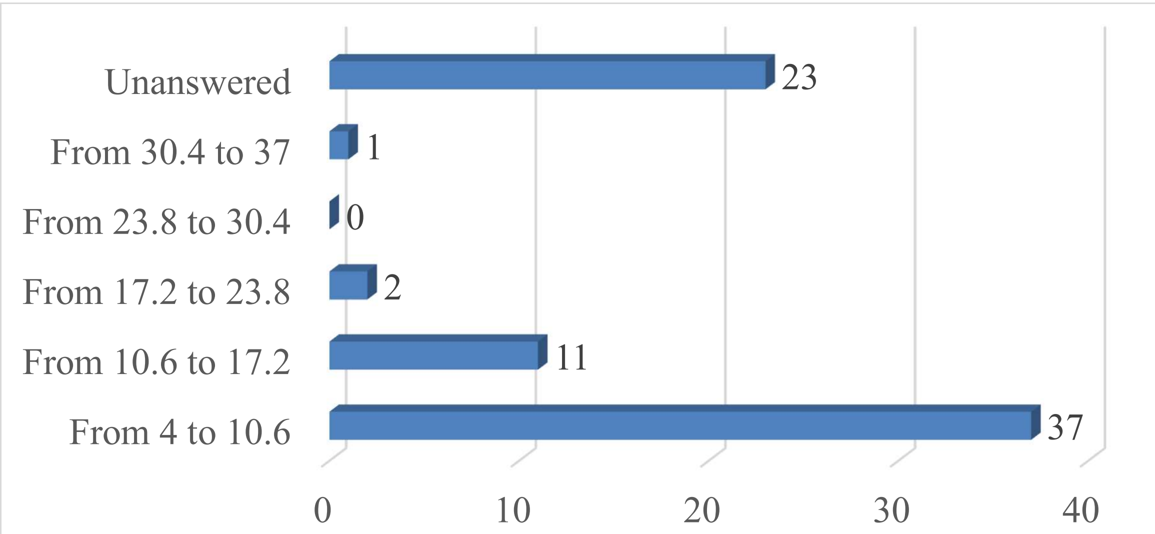


Chart 2. The size of the vessels surveyed (meters)

The research was conducted on the basis of five pre-defined characteristics with seventeen elements, as follows:

The five groups of factors rated by users on a Likert scale are:

1. Safety of navigation, three of them related to:
    a) The existence of underwater installations;
    b) Potential dangers in the navigation process;
    c) Manoeuvre space.
2. Hydrometeorological factors, two of them referring to:
    a) Protection of the area during the stay at the anchorage;
    b) Sea currents and tides.
3. Spatial, three of them referring to:
    a) Distance and depth;
    b) Turning radius required by the vessel; and
    c) Occupying space.
4. Economic factors, five of which relate to:
    a) Proximity to the port area;
    b) Proximity to the public anchorage;
    c) Access to land;
    d) State of traffic and other infrastructure, and
    e) Profitability.
5. Ecological and environmental factors, four of them relating to:
    a) Impact on nature;
    b) Disruption of the seabed;
    c) Pollution and waste, and
    d) Importance and state of local heritage.

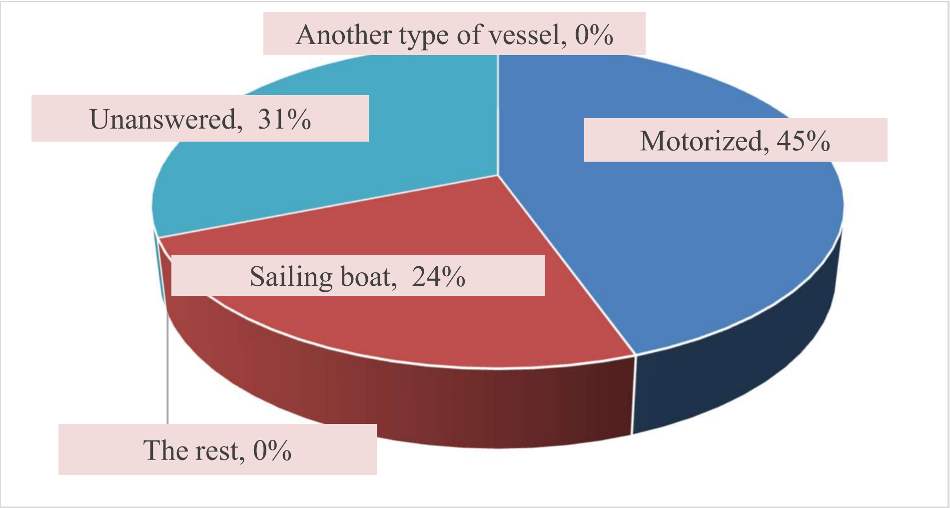


Chart 3. Type of vessels surveyed

Table 4 shows the results obtained on the basis of the survey.

Table 4. Structure of respondents surveyed

Number of respondents		**74**
Occupation	**74**	**100%**
Professionals	45	61%
Recreationists	26	35%
The rest	3	4%
Vessel owner	**74**	**100%**
Yes	51	69%
Not	23	31%
Vessel size (m.)	**74**	**100%**
From 4 to 10.6	37	50%
From 10.6 to 17.2	11	15%
From 17.2 to 23.8	2	3%
From 23.8 to 30.4	0	0%
From 30.4 to 37	1	1%
Unanswered	23	31%
Type of vessel	**74**	**100%**
Motorised	33	45%
Sailing boat	18	24%
Another type of vessel	0	0%
The rest	0	0%
Unanswered	23	31%
1. Safety of navigation		
1.1 Underwater installations	**Mean grade**	**4.58**
1	1	1%
2	2	3%
3	6	8%
4	9	12%
5	56	76%
Total	**74**	**100%**

1.2 Potential danger	**Mean grade**	**4.51**
1	0	0%
2	2	3%
3	10	14%
4	10	14%
5	52	70%
Total	**74**	**100%**
1.3 Manoeuvring space	**Mean grade**	**3.97**
1	2	3%
2	4	5%
3	16	22%
4	24	32%
5	28	38%
Total	**74**	**100%**
2. Hydrometeorological factors		
2.1 Bay protection	**Mean grade**	**4.41**
1	1	1%
2	1	1%
3	7	9%
4	23	31%
5	42	57%
Total	**74**	**100%**
2.2 Current and tide	**Mean grade**	**3.26**
1	7	9%
2	8	11%
3	32	43%
4	13	18%
5	14	19%
Total	**74**	**100%**
3. Spatial criteria		

3.1 Distance and depth	**Mean grade**	**4.03**
1	0	0%
2	6	8%
3	15	20%
4	24	32%
5	29	39%
Total	**74**	**100%**
3.2 Turning radius	**Mean grade**	**4.26**
1	0	0%
2	4	5%
3	12	16%
4	19	26%
5	39	53%
Total	**74**	**100%**
3.3 Occupying space		
to 25%	22	30%
to 50%	24	32%
to 75%	14	19%
to 100%	7	9%
Other	7	9%
Total	**74**	**100%**
4. Economic criteria		
4.1 Port area	**Mean grade**	**2.82**
1	16	22%
2	13	18%
3	22	30%
4	14	19%
5	9	12%
Total	**74**	**100%**
4.2 Public anchorage	**Mean grade**	**3.30**
1	9	12%
2	9	12%
3	21	28%
4	21	28%
5	14	19%
Total	**74**	**100%**
4.3 Access to land	**Mean grade**	**2.81**
1	13	18%
2	14	19%
3	29	39%
4	10	14%
5	8	11%
Total	**74**	**100%**
4.4 Traffic and other infrastructure	**Mean grade**	**2.55**
1	18	24%
2	19	26%
3	22	30%
4	8	11%
5	7	9%
Total	**74**	**100%**
4.5 Profitability	**Mean grade**	**3.19**
1	5	7%
2	10	14%
3	32	43%
4	20	27%
5	7	9%
Total	**74**	**100%**
5. Environmental criteria		
5.1 Impact on the environment	**Mean grade**	**3.74**
1	7	9%
2	2	3%
3	19	26%
4	21	28%
5	25	34%

Total	**74**	**100%**
5.2 Seabed disturbance	**Mean grade**	**3.84**
1	7	9%
2	5	7%
3	14	19%
4	15	20%
5	33	45%
Total	**74**	**100%**
5.3 Pollutants or waste	**Mean grade**	**4.27**
1	3	4%
2	2	3%
3	11	15%
4	14	19%
5	44	59%
Total	**74**	**100%**
5.4 Local heritage	**Mean grade**	**4.15**
1	4	5%
2	3	4%
3	11	15%
4	16	22%
5	40	54%
Total	**74**	**100%**

Among the safety of navigation criteria, sailors assigned the greatest importance to underwater facilities (mean score 4.58), followed by potential hazards (4.51) and manoeuvring space (3.97).

Out of the hydrometeorological criteria relevant to nautical anchorages, sailors place the greatest importance on nautical anchorage protection (4.41), followed by currents and tides (3.26).

In terms of spatial criteria, users attribute the greatest importance to the turning radius (4.26), followed by the distance of the nautical anchorage from the coast (4.03).

The most significant economic criteria from users' perspective are: 1. Proximity to a public anchorage (3.30); 2. Proximity to the port area (2.82); 3. Access to land (2.81); and last, 4. Transport and other infrastructure (2.55).

Among the environmental criteria, users placed the highest value on the following criteria: 1. Pollutants and waste (4.27); 2. Local heritage (4.15); 3. Seabed disturbance (3.84); and 4. Impact on nature (3.74). (Table 5.)

Table 5. Criteria by groups from larger to smaller according to mean user ratings

Criterion name	Mean grade
1. Safety of navigation - 1.1 Underwater installations	4.58
1. Safety of navigational - 1.2 Potential danger	4.51
1. Safety of navigation - 1.3 Manoeuvre space	3.97
Mean grade	4.46
2. Hydrometeorological criteria - 2.1 Bay protection	4.41

2. Hydrometeorological criteria - 2.2 Currents and tides	3.26
Mean grade	3.83
3. Spatial criteria - 3.2 Turning radius	4.26
3. Spatial criteria - 3.1 Distance and depth	4.03
Mean grade	4.14
4. Economic criteria - 4.2 Public anchorage	3.30
4. Economic criteria - 4.5 Profitability	3.19
4. Economic criteria - 4.1 Port area	2.82
4. Economic criteria - 4.3 Access to land	2.81
4. Economic criteria - 4.4 Traffic and other infrastructure	2,55
Mean grade	2.94
5. Environmental criteria - 5.3 Pollutants or waste	4.27
5. Environmental criteria - 5.4 Local heritage	4.15
5. Environmental criteria - 5.2 Seabed disturbance	3.84
5. Environmental criteria - 5.1 Impact on nature	3.74
Mean grade	**4.00**

The survey shows that sailors place the most importance on safety and the least on economic factors, as shown in Table 6.

Table 6. Survey result - sorted mean grades (from highest to lowest)

The name of the criterion	mean grade
1. Safety of navigation - 1.1 Underwater installations	**4.58**
1. Safety of navigation - 1.2 Potential danger	4.51
2. Hydrometeorological criteria - 2.1 Protection of the bay	4.41
5. Environmental criteria - 5.3 Pollutants or waste	4.27
3. Spatial criteria - 3.2 Turning radius	4.26
5. Environmental criteria - 5.4 Local heritage	4.15
3. Spatial criteria - 3.1 Distance and depth	4.03
1. Safety of navigation - 1.3 Manoeuvre space	3.97
5. Environmental criteria - 5.2 Seabed disturbance	3.84
5. Environmental criteria - 5.1 Impact on the marine environment	3.74
4. Economic criteria - 4.2 Public anchorage	3.30
2. Hydrometeorological criteria - 2.2 Currents and tides	3.26
4. Economic criteria - 4.5 Profitability	3.19
4. Economic criteria - 4.1 Port area	2.82
4. Economic criteria - 4.3 Access to land	2.81
4. Economic criteria - 4.4 Traffic and other infrastructure	2.55

The results of the survey show that in all the important criteria and factors relevant to the nautical anchorages, the sailors emphasise the safety factors, namely: distance of the existing underwater installations from the anchorages; protection of the anchorage from wind and waves; the size of the manoeuvring area, etc., so that in the second part of this dissertation, in the application of the MCA methods, the criteria: safety of navigation, protection of the anchorage, the surface of the anchorage, the surface of the bay, distance from the coast, as well as the environmental criteria are weighted the highest.

4.2. Analysis of the current state of nautical moorings in the SDC

The Split-Dalmatia County (Figure 4), with its seat in Split, is the largest county in Croatia in terms of area, covering 14,045 km², of which 4,572 km² (32.%) is land, and about one-third of Croatia's coastal sea, with an area of 9,473 km² (67.5%).

The county has a population of 455,242, of which 67% reside in the coastal area, 7% on the islands, and 26% in the coastal area.

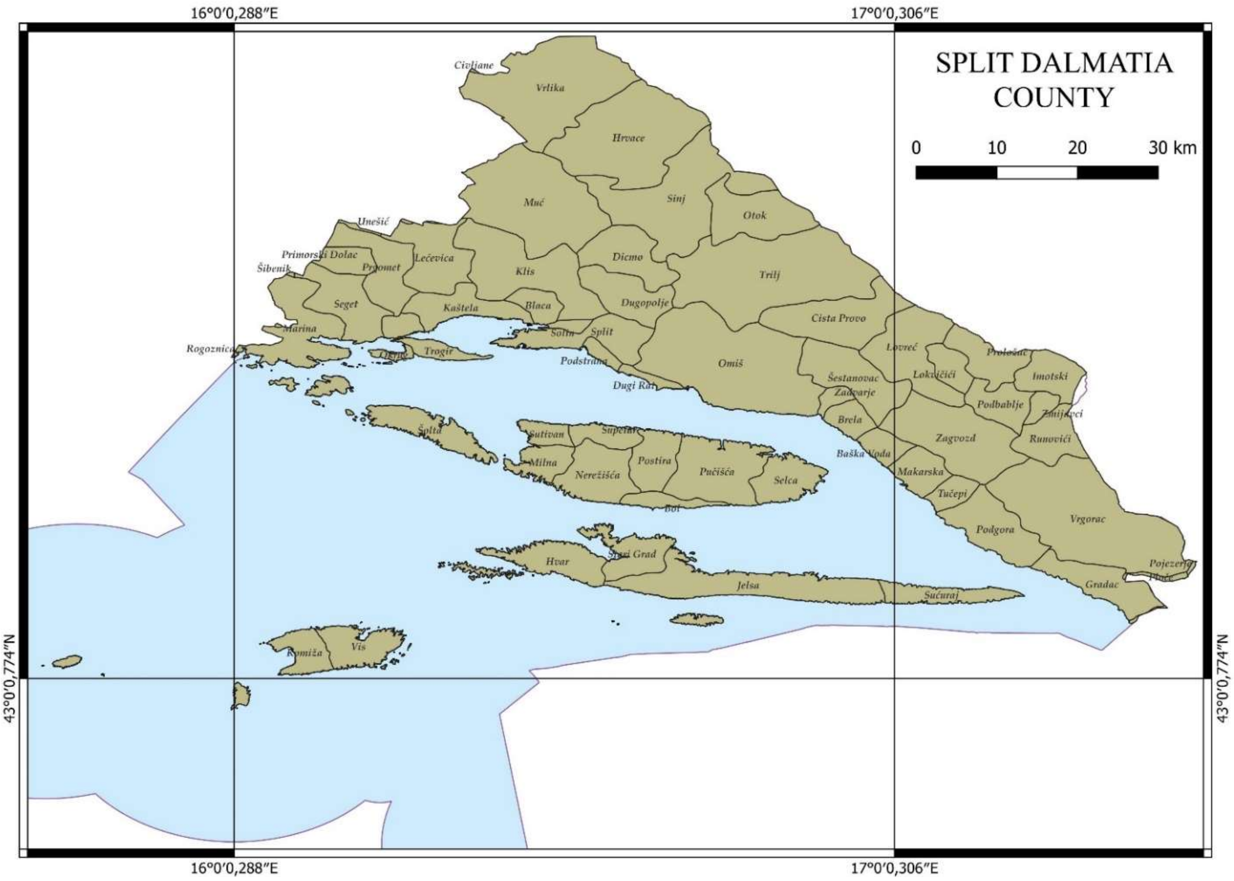


Figure 4. Map of SDC

Source: [71]

In the area of SDC prevails the Mediterranean climate, in Zagora (the hinterland) it is modified Mediterranean, and in the higher areas, it is Mediterranean with continental and mountain influences, and mountain climate.[72]

The ever-increasing number of vessels that arrive on the Croatian coast every year for transit or for a longer or shorter stay indicates the great and ever-growing importance of nautical tourism for the population and economy of Croatia.

The ports of nautical tourism in Croatia during 2019 are shown in Table 7.

Table 7. Ports of nautical tourism in Croatia in 2019.

County	Total	Anchorage	Mooring	Marina								Shipyards
				Dry marina	Category I marine	Category II marine	Category III marine	Marina 2 anchors	Marina 3 anchors	Marina 4 anchors	Marina 5 anchors	
Republic Croatia	**167**	**75**	**9**	**17**	**5**	**13**	**17**	**7**	**9**	**7**	**3**	**5**
Primorsko-Goranska	33	9	3	7	1	1	3	2	-	2	2	3
Zadar	47	31	2	4	-	4	4	-	-	-	-	2
Sibenik-Knin	30	15	-	1	2	2	5	1	2	2	-	-
Split-Dalmatia	**31**	**15**	**1**	**4**	**-**	**3**	**3**	**2**	**1**	**2**	**-**	**-**
Istria	13	-	1	-	2	1	2	1	4	1	1	-
Dubrovnik-Neretva	13	5	2	1	-	2	-	1	2	-	-	-

Source: [73]

Table 8. displays the overall operating capacities of Croatia's tourist ports for the years 2018 and 2019.

Table 8. Total capacity of nautical ports in Croatia for the period 2018-2019.

	2018	**2019**
Water area of the port, m2	4,075,400	4,349,270
Number of berths, total	17,274	18,179
Of this for vessels of length		
Up to 6 m	597	674
6 - 8 m	1,247	1,246
8 - 10 m	2,736	2,840
10 - 12 m	4,434	4,511
12 - 15 m	4.862	5,116
15 - 20 m	2,699	2,984
More than 20 m	699	808

The length of the developed coast for the mooring of vessels, m	64,844	67,587
No. berths for vessels on land	4,780	5,551
Total surface area on land, m^2	745,453	786,238
Of this, covered space (hangar), m^2	9,256	15,353
Number of employees, total	1,741	1,901
Of that seasonal	432	461
SDC		
Water area of the port, m^2	574,862	588,432
Number of berths, total	2,370	2,446
Number of berths for vessels on land	753	873
Total surface area on land, m^2	95,032	102,832
Number of employees, total	398	394
Of that seasonal	93	82

Source: [72]

As of December 31, 2019, there were 14,249 vessels at fixed berths in maritime tourist ports. This was 4.6% more than on December 31, 2018, with 84.9% of vessels using berths at sea and 15.1% only on land.

The majority of vessels at fixed berths are sailing yachts (49.0%), followed by motor yachts (46.4%) and other vessels (4.6%).

44.1% of vessels have a fixed berth under the flag of Croatia, 15.6% under the flag of Austria, 15.5% under the flag of Germany, 5.0% under the flag of Slovenia, and 3.8% under the flag of Italy.

According to the length of the vessel, the largest number of vessels for which mooring at sea was employed is 12 to 15 meters long, i.e. 32.0% of the total number of vessels for which mooring at sea was applied. Vessels ranging 10-12 meters in length account for 29.1% of the total number of vessels for which mooring at sea was used.

In 2019, there were 204,858 vessels in nautical tourism ports, a 5.5% increase compared to 2018.

The majority (64.9%) of the vessels using the sea berth for transit were sailing yachts, followed by motor yachts (29.1%) and other vessels (6.0%). In 2019, most vessels in transit came from Croatia (47.8%), Italy (14.1%), Germany (12.2%), Austria (7.0%), and Slovenia (4.1%), which accounted for 85.2% of the total number of vessels in transit.[72]

SDC ranks first in terms of the number of vessels in transit for which a sea berth was utilised. In 2019, SDC recorded the highest number of vessels in transit for which a sea berth was used. There were 55,343 vessels, representing 27.3% of the total number of vessels in transit for which a sea berth was used. Compared to 2018, there was a slight increase of 0.6% in the number of vessels in transit in SDC.

The revenue of ports from nautical tourism increased by 7.2% in 2019 compared to 2018. The ports' total revenue from nautical tourism amounted to HRK 918 million in 2019. Of this, HRK 652 million was from berth rentals, accounting for 71.0% of total revenues. Compared to 2018, total revenues improved by 7.2%, and revenues from berth rental increased by 5.4%.

In 2021, there were 210,071 vessels in transit in the ports of nautical tourism in Croatia, which means an increase in the number of ships in transit by 72.8% compared to 2020, when there was a large and negative impact on the arrival of vessels due to the pandemic of the disease COVID-19 and epidemiological measures against the spread of the disease both in Croatia and in the world. Compared to the year before the pandemic in 2019, the number of vessels has also increased by 2.5%.[74]

The data on the number of ports, the number of ships with permanent connections, the number of ships in transit, as well as the nautical tourism revenue generated in SDC ports were taken from the Croatian Institute of Statistics for the period 2005-2021 and are presented in Table 9.

The need to address the lack of vessel berths is becoming more and more obvious at the specialised ports and anchorages along the Croatian coast, particularly during the tourist season. Due to the rugged coastline, the number of potential anchorages on the Croatian coast and in SDC is relatively large, so in addition to marinas, ports and harbours, any larger bay can be considered a potentially good anchorage.

SDC has one national port - Split - and 51 county and local ports.[75]

There are 17 ports for nautical tourism, of which: 12 marinas, 2 anchorages, 2 berths and 1 unclassified port with a total of 2,021 berths, 503 berths for vessels on land.[76]

According to the spatial plan of SDC, there are 65 ports for public transport, 2 commercial-industrial ports, two fishing ports and two service bases for marine equipment. In addition, a larger number of anchorages are planned.[77]

Table 9. Statistical data on the number of ports, the number of vessels at a fixed berth, the number of vessels in transit, and the revenue generated in nautical tourism ports in the SDC area for the period 2005-2021.

Year	Number of ports	Number of vessels at permanent berth in ports of nautical tourism	Number of vessels in transit in ports of nautical tourism	Generated income in nautical tourism ports in thousands of HRK
2005	11	1,130	34,940	44,224
2006	11	1,196	35,677	50,679
2007	11	1,240	38,304	58,581
2008	11	1,254	37,125	58,668
2009	13	1,401	33,718	72,580
2010	13	1,445	36,465	78,982
2011	13	1,473	36,196	86,666
2012	16	1,337	41,944	100,951
2013	17	1,441	44,649	102,730
2014	21	1,588	49,509	122,688
2015	20	1,755	50,562	146,284
2016	27	1,950	52,995	159,380
2017	27	1,928	55,412	180,091
2018	29	1,954	55,290	197,852
2019	31	2,064	55,633	206,936
2020	31	2,077	28,468	170,860
2021	40	2,306	59,768	211,106

In 2021, in Split-Dalmatia County, there were the most vessels in transit for which a berth at sea was used, namely 59,349 vessels, which represents 29.2% of the total number of vessels in transit for which a berth at sea was used.[76]

As the valid spatial „*plan of SDC*"[78] does not provide for defined anchorages, the possibility of equipping the existing maritime waters for anchoring and accommodating vessels continues to be largely based on the lists published in the official maritime publications. The creation of a spatial plan and the "Study of Anchorages of Split-Dalmatia County" were initiated by the Administrative Department for Tourism and Maritime Affairs in 2016 in compliance with the SDC Statute.[37]

The aforementioned study forms a qualitative basis for amendments and the adoption of a new spatial plan SDC, which, based on safety, meteorological, technical-technological and traffic factors, includes measures for maritime safety and habitat maps of the Natura 2000 ecological network with a list of protected species, as well as technical-technological methods and the organisation of anchorages, the spatial scope of possible concession areas, special ports, anchorages, as well as the conditions that future investors must meet in order to obtain the necessary permits and work authorisations. In the first and second phase of the study, which was completed in 2018, fifty-one locations of special ports/anchorages and eighty-five concession areas were proposed, the total area of which is approximately 849,449 m^2, including the area of the Central Dalmatian islands and part of the mainland of SDC with thirteen local self-government units.

Forty-one locations were analysed in Phase I of the study, thirty of which falling within the scope of the Natura 2000 ecological network, and twelve sites were analysed in Phase II, ten of which falling within the scope of the Natura 2000 ecological network.

The second phase, which was completed in 2019, involved analysing an additional twelve locations. It is a follow-up to the earlier study and deals with nine additional areas, three of which are included in the Natura 2000 natural network.[37]

The recommendations for anchorages that came out of the study take into consideration a variety of factors, including the needs of sailors, current concessions and solutions, as well as spatial limitations, maritime traffic, the impact of hydrometeorological factors, general safety and risk assessment when approaching and remaining at anchorages, and the preservation of the sea and the underwater environment from pollution. In general, taking into account the above factors, all the studied anchorages represent a compromise solution, the establishment of which would satisfy all the needs of anchored vessels in the area, especially during the summer months.

There are twelve marinas on the territory of SDC classified into corresponding standards based on the extent to which the regulation for each category have been met, as well as other amenities and services that sailors can access nearby and the overall standard of maintenance of the marina as a whole.[79]

The nautical season in SDC lasts from Easter to October, and the beginning of the year itself is usually reserved for investments in marina infrastructure and various technical and other improvements. The area of SDC is the most favourable destination for navigators, and the biggest advantages of this area are the safety of navigation and the clear sea. The currently used anchorages in the SDC area (Figure 4) are mostly not equipped with commercial infrastructure, although the introduction of municipal services at the anchorages would probably contribute to their greater use and commercialisation. Artificial protection of the anchorage by building a breakwater at the anchorage is not allowed, regardless of the water area of the bay.

Unprotected or open anchorages are suitable for anchoring in fine weather or in areas where the wind comes from the land and there are no waves. Natural anchorages used for the safe anchoring of vessels, are usually listed in maritime publications, and marked on nautical charts and are characterised by naturally preserved features. Concessionaires are generally not interested in them as they are typically in public use and charging anchorage fees there would be difficult.

In order to protect nature, it is forbidden to dispose of waste and waste water of any kind in the sea at such moorings.

Nautical moorings are equipped with systems for mooring vessels - buoys and are often the subject of interest for economic use, i.e. investors/concessionaires.

Nautical berths can be leased/concessioned, with the investor charging for their use. Berths are included in the spatial plan, and a number of permits: location, construction, concession, and others are required when the concessionaire determines the future facility and use. Around the berth, at a distance of 50 to 150 meters from its outer boundary, there is a protected area of the berth[58], the framework of which is determined and covered by the harbour master.

Experts believe that the disputable distances of the protective belt of 150 or 300 meters are absolutely unacceptable. The law, not the regulation, should prescribe the maximum protected area of the nautical anchor no wider than 50 meters, only exceptionally up to 100 meters.

Each specific micro situation of the nautical anchorage and the safety of navigation should be considered by the harbour master office when determining the protective zone of the nautical anchorage in a maximum width of up to 50 meters and up to 100 meters. In some cases, which cannot be determined in advance, the protective belt of the nautical anchorage is simply unnecessary. Such circumstances should be left to the professional judgment of the harbour master, whose primary duty is to ensure safety at sea. In any case, a proper balance should be struck between the interests of boaters, the general use of maritime property, and the interests of the holder of the nautical mooring concession.

The Law on Maritime Domain and Seaports[35] and the Regulation on the Procedure for Granting Maritime Domain Concessions[36] define the granting of nautical mooring concessions as objects of economic use, although in the opinion of experts from SDC they are not sufficiently defined.[80]

In 2014, The Ministry of Sea, Transport and Infrastructure[81] published a list of 23 licensed nautical anchorages on the territory of SDC, specifically:[82]

1) Bay Zavala, Stari Grad (cadastral municipality);
2) Bay Lučice (eastern part), Milna (cadastral municipality);
3) Bay Lučice - Smrčeva, Brač Island;
4) Cadastral municipality Pučišća, Brač Island;
5) Komiža - area off Jastožere, Vis Island;
6) Komiža - area Pul Guspu, Vis Island;
7) Bay area Osibova, Brač Island;
8) Bay area Lučice (eastern part), Brač Island;
9) Area port Vića, Brač Island;
10) Bay area Bobovišća, Brač Island;
11) Bay area Stončica, Vis Island;
12) Bay area Tiha, Hvar Island;
13) "A" Bay Malo Stupišće;
14) Bay area Tiha, Hvar Island;
15) "B" Bay Veliko Stupišće, western part;
16) Bay area Tiha;
17) Bay area Tiha, Hvar Island "D" Uvala Vučja;
18) Bay area Tiha, Hvar Island "E" Uvala Mlitki Bok;
19) Bay area Tiha, Hvar Island "F" Uvala;
20) Bay area Tiha, Hvar Island "G" Uvala;
21) Bay area Tiha, Hvar Island "H" Uvala;
22) Bay area Tiha, Hvar Island "I" Uvala Paklena;
23) Bay area Lučice (western part), Municipality Milna.

In 2022, there were 17 licensed anchorages in SDC that were safe and organised. However, legal procedures were only partially followed. Although concessions are regularly tendered for a period of 10 years, most concessionaires operated illegally, often placing more buoys than allowed, charging higher fees than allowed, polluting the water surface, etc. Because of the non-compliance with the law, the Port Authority of SDC constantly tightens the supervision of the operation of the nautical anchorages and threatens the concessionaires with the loss of the right to use them.

However, due to the low and often ineffective penalties, most concessionaires continue their activities shortly after the penalty is imposed. This shows the need for a clearer, but simpler, more efficient and precise definition of the legal and other procedures that regulate and establish the conditions of use and operation.[37]

An important step in the construction of nautical anchorages is the selection of a location. In defining the criteria for the installation of nautical anchorages, the land use plans are of particular importance, as they contain an accurate and detailed elaboration of the conditions for all accommodations.

The location should be analysed, and the evaluated criteria should be taken into account, based on which the most suitable ones should be selected.

5. MCA METHODS FOR RANKING MOORING FIELDS

5.1. Definition and description of MCDM methods

There is a strong belief that any representation of a complicated system reflects only a subset of its possible representations. A system is complicated if the relevant aspects of a particular problem cannot be captured by a single representation.[83]

To complicate matters further, systems, including humans, are reflexively complicated. Reflex systems have two aspects: "*consciousness*" and "*purpose*," both of which require an additional "*leap*" in describing complexity.

The existence of different levels and scales at which a hierarchical system can be analysed necessarily implies the existence of its non-equivalent descriptions.[84]

A simple description of, say, geographic orientation is not possible without making an arbitrary subjective decision at the level of the system in question.

Therefore, the problem of multiple identities in complicated systems can be interpreted as non-equivalent observation not only in terms of non-equivalence of observers, but also in terms of ontological properties of the observed system.

Because today's decisions are complicated, they combine hard facts with the intuition of experts, so rapid decision-making in business often requires the collaboration of experts from different fields, control over spatio-temporal data, effective planning, good organisation, and good time management.

In the field of business decision support, more and more research[85] is focusing on the human side of the interaction of people, technology, and information technologies. Many works have shown that the enterprise decision environment is a unity of decision makers' experiences, beliefs, and perceptions on the one hand, and decision support tools and techniques on the other.

The information environment surrounding business activities and decisions is becoming increasingly complicated due to the growing amount of information potentially relevant to specific business activities.[86]

The decision support system helps analysts to answer questions about the application of science in the decision-making process, which method of analysing multiple decision criteria in the group of MCA methods is best suited to solve a particular problem and/or make decisions more efficiently.

The MCA methods provide guidance for the decision-making process and selection from an extensive collection (more than 200) of methods. They are evaluated according to the original groups of problem characteristics.

Accordingly, there are numerous descriptions of multi-criteria decision processes[87] and preference modelling.[85]

Applications of MCA techniques generally include:[88]

1. The selection of possible decision options;
2. The selection of evaluation criteria;
3. The determination of performance measures and their fulfilment;
4. The conversion of data into proportional units, depending on the type of multi-criteria method used, which usually requires the input of the preferences of the decision makers.

Given the above, MCA provides a framework for evaluating decision options based on multiple criteria. There are numerous techniques for solving multi-criteria decision and analysis problems.

Regardless of the definitions, MCA methods generally assume that the decision maker must choose among multiple options or alternatives. A group of alternatives represents a set of all possible solutions. The selection of alternatives from a group depends on many, often conflicting, properties, called decision criteria. Therefore, decision makers usually have to choose a compromise solution.

Multi-criteria evaluation is primarily concerned with the problem of how to combine information from multiple criteria into a unique evaluation index to make a comparative assessment between projects or heterogeneous measures. In the field of evaluation, MCA is usually a precise evaluation tool and is particularly used to study strategic decisions and decision interventions.

In ex post evaluations, MCA can contribute to the assessment of a program or policy by evaluating its impact in relation to selected criteria.

Because of its successful development over the last 50 years, MCA is used in many areas, such as resource management, to ensure that resources, i.e. availabilities are used in a reasonable and most acceptable way. MCA also plays an important role in selecting the best variants for finding the best areas - locations in many areas of spatial planning, optimisation of urban and non-urban structures, etc. According to "*Multi-criteria analysis: A manual*", published by Communities and Local Government London, the method of MCA is defined as an approach that explicitly identifies all options and their contributions, and on the basis of which a decision support is subsequently realised.[89,90]

In the 1970s and early 1980s, numerous multi-criteria methods were developed and used for different purposes and in different contexts.

Decision-making is a process of choosing between alternatives based on multiple criteria. In any decision, there are factors or criteria that must be considered and multiple alternatives among which the decision maker can choose. In group decision-making, the criteria and alternatives are more obvious and must be established before they are assigned an evaluation value.

The determination of criteria and alternatives is highly subjective. The list of criteria and alternatives is not exhaustive and does not cover all possible criteria or alternatives. There is no right or wrong criterion, as these are subjective considerations. Different decision makers may prefer or reject one criterion over another, some factors may be combined, and some criteria may be subdivided into more detailed criteria or sub-criteria.

The above shows that most decisions are based on the individual judgments of the decision maker. While the decision maker tries to decide as rationally as possible, subjective opinions can also quantify subjective values. Criterion values can be given in a range, e.g. from 1 to 20 or -5 to 5, and can refer to real numbers that represent the real dimension of what can be selected: length, width, number, etc. The values may represent any real number, a range or an interval, or a value for each of the factors. The higher value usually means a higher factor level or a desirable value. In this respect, it is obvious that not only the criteria and alternatives are subjective, but also the values are subjective and depend on the decision maker.

5.2. Terminology, application requirements, and MCA method components

An expert system is a knowledge-based computer program that contains knowledge from an expert domain about objects, events, situations, and courses of action, and mimics the process of human experts in a particular domain.

A knowledge base stores rules, facts, and other knowledge structures for long-term use, much like a database stores data. Mathematical models are used in the decision-making process in business, especially in negotiations, because decision-making and negotiations require logical thinking to consider a large number of factors simultaneously.

The application of mathematical methods offers a new approach to qualitative and quantitative problems, and so it is not surprising that more and more mathematical tools, techniques, and models are being used in decision making and negotiations.[86]

One of the most common challenges in the field of spatial planning is the selection of the most suitable location for the construction or installation of certain objects with a specific purpose and the fulfilment of expectations, such as technical and other conditions that are set in the selection process.

The decision process is determined by the following elements:[91]

- Decision maker;
- A set of decision alternatives;
- A set of criteria;
- A set of objectives.

Accordingly, decision makers are those who select the most favourable option(s) from a large number of possible options.

The process of selecting the spatial location of nautical anchorages involves:

- The identification of a range of influencing factors relevant to site selection;
- The prediction, evaluation of the intensity and direction of their impact over time and under the given conditions;
- The evaluation of the possible variants of the solution and the selection of the optimal variant.

The calculation of the factors and criteria related to the formulation of the problem, the identification of the preferences and the types of information about the preferences, the desired characteristics of the preference model and the preparation of recommendations for decision making in the process of selecting the best locations for nautical moorings consists of five phases, which are shown in Figure 5.

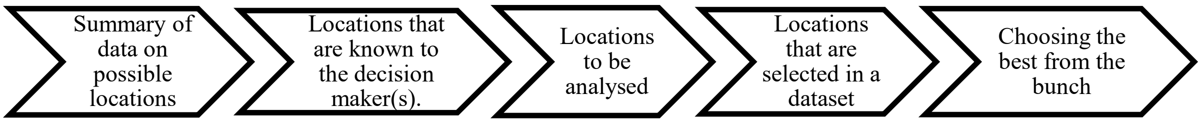


Figure 5. The process of selecting the best locations for nautical anchorages

Source: [Author]

The applicability of the selected MCA method(s) will be tested through a case study and will include the following options:

1) Develop very simple to very complicated decision models;
2) Provide recommendations for the development of decision models that do not conform to the MCA method;
3) Assisting analysts and decision makers in setting priorities to reduce gaps in the problem description for decision support; and
4) Uncovering methodological errors that occur when certain methods are chosen.

The initiative at the level of the whole process includes expert opinions and knowledge of the methodology of MCA, analysts and other decision makers and participants in this process, including their recommendations that contribute to the efficiency and simplicity of the application of MCA methods in the field of spatial planning and selection of the best locations for nautical anchorages.[92]

The group of decision alternatives ***V*** represents a set of possible actions at a given time. The group of decision criteria ***C*** represents a set of parameters that define the process and on the basis of which a comparison of alternatives is made.

The decision criteria are characterised by numerous levels that depend on the various alternatives and/or the state of the unbiased conditions. All these levels can represent decision objectives that can be achieved from the point of view of the defined criteria. Decision models with a group of criteria, also called multi-criteria decision models, can be multi-attribute decision models or multi-objective decision models and are subject to linear programming.[93]

The effect of scale on multi-attribute evaluation is very important, especially when creating evaluation criteria.

Multi-attribute decision models consist in determining the optimal variation from a set of finite variants $V = \{V_1, V_2, ..., V_m\}$, which are compared with respect to assigned numerical or non-numerical values belonging to the finite set of criteria $C = \{C_1, C_2, ..., C_n\}$. Each criterion may aim to achieve a maximum or minimum value.

In multi-attribute decision problems where the sequence matrix contains heterogeneous, numeric or non-numeric data, the homogenisation of these data is done by the normalisation process,[94] which transforms the sequence matrix into the matrix $\boldsymbol{R= (r_{ij})\ i=1,m; j=1,n\}}$ in elements on a certain interval, for example, from 0 to 1 [0,1] or from -1 to +1 [-1,+1], and so on.

In almost all multi-attribute decision problems, there is information about the degree of importance of each criterion. This is generally expressed by the vector $\boldsymbol{P=\{p_1, p_2, ..., p_n\}}$ and indicates the degree of importance that the decision maker attaches to each criterion. Each multi-attribute decision problem can be expressed by a matrix ***A*** called the consequence matrix (decision matrix) (Table 10), where the elements $\boldsymbol{a_{ij}}$ indicate the evaluation - consequence of variant $\boldsymbol{i, i=1, 2, ..., m\ (V_i)}$,, by criterion $\boldsymbol{j, j=1, 2, ..., n, (C_j)}$.

Table 10. Decision or consequences matrix

V_j \ C_i	C_1	C_2	...	C_n
V_1	a_{11}	A_{12}	...	a_{1n}
V_2	A_{21}	A_{22}	...	A_{2n}
...	...	...	...	...
V_m	a_{m1}	a_{m2}	...	a_{mn}
P	p_1	p_2	...	p_n

Source: [93]

Multi-attribute decision methods fall into three categories,[95] specifically:

1. Direct methods;
2. Indirect methods; and
3. Methods that use a specific distance to construct hierarchies.

Direct methods build a function defined on a set of variants with real values and select the variants for which the objective function f has the largest value.

Indirect methods determine a hierarchy for a set of variants based on an algorithm.

Methods that use distance (TOPSIS) select the variant that is closest to the ideal solution. The details are described in Section 5.4 and defined by formulas 5.4.6, 5.4.7 and 5.4.8.

In this dissertation, several direct methods that use simple additive weighting method and methods using distance (TOPSIS, AHP-TOPSIS-2N, PROMETHEE II) are used.

Multi-criteria decision methods are a group of methods that can be used to compare alternatives. MCA methods consist of a group of approaches that allow multiple criteria to be explicitly considered to help individuals or groups rank, select, and/or compare different alternatives, e.g. locations, products, technologies, strategies, etc.

In the past, new methods were found and the methodology of the decision-making process was perfected. Decision problems are usually about choosing the best compromise solution.[96]

Besides the actual criterion values according to which the decision is made, the selection of the best solution also depends on the decision maker, i.e. his individual preferences. Numerous mathematical methods have been proposed to simplify the decision-making process.[97]

Empirical studies have been conducted using MCA methods: AHP, TOPSIS based on combinatorial mathematics; PROMETEE II as well as the combined, hybrid method AHP -

TOPSIS-2N, and on the basis of the opposing criteria and the weighting values assigned to them, depending on their actual importance in the decision-making process, the best location of the nautical anchorage, as possible variants in SDC was selected.

Details about the initial situation, the method of calculating the best solution for each of the applied methods of MCA can be found in Chapters 5.3, 5.4, 5.5 and 5.6.

The entire process of determining the best locations for nautical moorings consists of two phases.

The first phase is based on surveys to determine the opinions, desires, and preferences of potential users regarding the conditions they believe should exist at moorings to make sailors feel safe at these locations.

Several groups of criteria were analysed and evaluated, the most important of which are the following: Safety of navigation, Hydrometeorology, Spatial Planning, Economy and Environment-ecology. They were discussed in more detail in the fourth chapter (4.1) of this dissertation, and therefore will not be further elaborated in the rest of this thesis.

They are at the same level, based on many years of fieldwork, but independent of the survey research and over a longer period of time, more than four years, the author of this dissertation collected, analysed, stored, processed, organised, completed, and evaluated the collected data while working in the field with GIS. The data includes information about all future planned locations of nautical anchorages in SDC and includes: Name and detailed description of the site; field surface; the surface of the bay; the proportion and/or percentage of field surface in the bay surfaces; the degree and partial protection of the bay based on protection from wind, waves and sea currents; the minimum distance of the fields from the coast, the potential number of fields of nautical anchorages in bays and much more. All the data collected and processed in this part is independent of the data collected from sailors through surveys, as the whole process should be considered from the point of view of numerous independent users, spatial planners and other interested persons.

Of course, all the points collected during the survey research in the first phase serve as benchmarks that allow for determining the weighting of the criteria in the second phase, depending on the type of MCA method applied.

These data, the results of the questionnaire, are also used in the validation of the obtained solutions through multi-criteria decision-making methods to determine how well the collected solutions meet the expectations of future users, i.e. sailors, and to analyse the quality of the selection of the best nautical anchorages.

In the following, the methods of MCA used in this research are explained in more detail.

5.3. AHP

AHP is a MCDM method originally developed by Prof. Thomas L. Saaty in the 1970s and has since undergone extensive research and improvement. It is now one of the most widely used analytical techniques and offers a thorough and rational framework for structuring and resolving multi-criteria decision problems.[98]

Briefly, it is a method for deriving ratio scales from pairwise comparisons. Input can be obtained from actual measurements such as price, weight, etc., or from subjective opinions such as feelings of satisfaction and preferences. AHP allows for some inconsistency in judgment because people are not always consistent, and therefore their decisions are not consistent.[98]

The AHP approaches to design the overall structure of the problem by identifying various goals and alternatives for achieving those goals. Therefore, AHP does not usually provide the ability to make only one correct decision, but rather many options from which the decision maker eventually selects or uses to support the achievement of organisational goals, plans, operations, and decisions. Using the AHP framework helps organisations make multiple decisions by evaluating and prioritising criteria. By using the AHP methodology, it is possible to make more informed decisions and help the team achieve planned outcomes.

The basic steps for solving decision problems using the AHP are quite simple:[98]

1. Structuring the decision problem in a hierarchy that defines the problem, the choices and the objective, and the purpose of the identified alternatives, the categories, and the decision criteria;
2. Comparison of pairs of criteria in each category - why one and not the other, etc., i.e. why something is preferred over something else, etc.;
3. Calculation of priorities and consistency index, whether the established comparisons are logical and consistent;
4. Evaluation of the alternatives according to the established priorities, i.e. which alternative is the optimal solution to the decision problem. In this part, the decision criteria and the associated alternatives are structured;
5. Evaluation - Evaluating the relative value of the different alternatives for each decision criterion and judging the relative importance of the decision criteria are the main evaluation methods in the AHP.
6. Group summary of judgments and analysis of inconsistencies in judgments;
7. Selection - In this step, a calculation of the weights and priorities of the various alternatives and criteria is made and a sensitivity and inconsistency analysis is performed.

Using the analytic hierarchy process for decision making/selection has many advantages. Scientists have developed many methods to make the right decision, but the AHP stands out from the crowd of MCA methods for the following reasons:

1. it is a proven formula, as it is one of the oldest and most reliable decision-making methods used by many in selecting the best options or implementing decisions;
2. it is versatile; it is used in a wide variety of fields and for very different problems and decision-making processes;
3. it is easy to use;
4. offers the possibility of defining numerous criteria.

The ratio scales are derived from the main *eigenvectors*, while the consistency index is derived from the main eigenvalue.

The normalised principal eigenvector is also called the priority vector. Since it is normalised, the sum of all elements in the priority vector is equal to 1. The priority vector shows the relative weights between the things being compared.

The AHP method is a mathematical framework for structuring the decision-making process that best highlights the most urgent tasks and priorities by comparing the importance of projects in pairs, such as comparing one strategy to another.[98] For example, one can compare the benefits of two different strategies in selecting the anchorage with the largest protected surface of the bay, selecting the location of the largest fields with the smallest number of fields, etc., assigning the highest numerical value to the criterion that has the greatest influence and importance. The AHP procedure is often found as a function in many analytical software programs.

The model consists of three parts:

1. definition of a general goal, challenge or decision;
2. definition of possible alternatives and solutions; and
3. definition of the criteria against which the solutions are measured.

AHP quantifies the criteria of potential alternatives and presents this information in a way that allows complicated decisions to be made.

After the goal is defined, the challenges are determined by dividing them into a group of subproblems. These smaller sub-problems can serve as the basis for establishing criteria. The division of the challenge into smaller subproblems can include new factors so that after the challenge and decision criteria have been defined, the criteria can be selected for further analysis of the solution.

An evaluation of the relative value of each criterion is performed by creating a pairwise comparison matrix in which the elements in the left column can be compared with the elements in the top column.

The matrix structure allows the input of numbers between 0 and 9, indicating the dominance of one element compared to another and visually representing the superiority of one criterion (rows) over another (columns).

By calculating the weights of the criteria and priorities during the decision process, the contribution of each criterion is determined. By weighing opinions on the criteria associated with the goal, a clearer idea of the best course of action emerges.

Table 11. Saaty scale of importance of intensity

Scale	Numerical evaluation	Reciprocal
Extremely desirable	**9**	**1/9**
Very strongly to extremely desirable	8	1/8
Very desirable	**7**	**1/7**
Very to very very desirable	6	1/6
Very desirable	**5**	**1/5**
Moderate to highly desirable	4	1/4
Moderately desirable	**3**	**1/3**
Equal to moderate preferred	2	1/2
Equally desirable	**1**	**1**

Source:[99]

According to [99], the steps of the AHP method, that are to be followed during implementation are described below:

Step 1: Develop a decision hierarchy by decomposing the entire problem into a hierarchy of parameters or criteria.

Step 2: Prioritise among the parameters or criteria of the hierarchy by making a series of judgments based on pairwise comparisons. In this step, the preferences among the criteria are evaluated based on Saaty's scale [98] from 1 to 9, and from 1/9 to 1. (Table 11)

Step 3: Synthesizing the judgment to obtain a set of general priorities for the hierarchy. In this step, the weighted results of the criteria are calculated, which give a relative ranking of the parameters or criteria;

Step 4: Comparing qualitative and quantitative information using informed judgments to derive weights and priorities to check consistency of judgments;

Step 5: Selecting the best alternative based on the available sample data and calculating the final score of each alternative.

In the MCDM method AHP, the decision-making problem is hierarchically structured, given that the decision-making problem is decomposed into subproblems that are analysed independently. At a certain level of the hierarchy, each element (criterion or alternative) is compared with each element of the same level.

Therefore, based on the matrix of real values (estimates) determined by x_{ij} values, for each criterion (*Cj, j=1,n* where *n* represents the total number of criteria) and each alternative *A* (A_i, *i=1,m,* where *m* represents the total number of alternatives) of the decision-making relationship, the input data are represented by the decision-making matrix *D* shown mathematically (Eqn.(*5.3.1*)).

$$D = \begin{matrix} & \begin{matrix} C_1 & \dots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ \dots \\ A_m \end{matrix} & \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \cdots & \cdots & \cdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \end{matrix} \tag{5.3.1}$$

The formulas used for solving the matrices in the AHP steps are given below, as well as the flowchart of the AHP steps.[100]

The results of the comparison by pairs of criteria are presented by a square matrix of comparison *A* of order *n x n*, where *n* is the number of observed criteria (alternatives at a later stage). The matrix element a_{ij} of matrix *A* represents the relative importance of criterion *i* in relation to criterion *j*. If a_{ij}>1, criterion *i* is more important than criterion *j*, while the reverse is true for a_{ij} <1. If two criteria are of equal importance, then a_{ij} =1.

For consistency, a_{ij} = 1/ a_{ij} holds for each *i,j*.

Therefore, a_{ij} = 1 holds for every *i*. Additionally, due to transitivity, $a_{ij} = \alpha ik \cdot \alpha kj$ should hold for every *i, j* and *k*. The preferences or relative importance of decision makers are expressed by Saaty's scale of relative importance, i.e. numbers from 1 to 9, and from 1/9 to 1.

The values of Saaty's scale of relative importance are found in Table 11.

Based on Saaty's scale of relationships between criteria, matrix A was formed. (Eqn. (*5.3.2*)

$$A = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & \cdots & 1/a_{n1} \\ 1/a_{12} & 1 & & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{pmatrix} \tag{5.3.2}$$

whose values along the main diagonal have values of 1.

The vector *B* (Eqn. ((*5.3.3*) and (*5.3.4*)) represents the sums of the elements of the matrix by rows, dimensions *n*.

$$B = \sum_{i=1}^{n} a_{ij} = b_i, j = 1 \quad (5.3.3)$$

$$B = (b_1 \quad b_2 \quad \dots \quad b_i), i = 1, n \quad (5.3.4)$$

Dividing each element of the matrix (of a certain column) with the elements of the vector *b*, the values of the normalised matrix *G*. (Eqn. (*5.3.5*))

$$G = \begin{pmatrix} \frac{a_{11}}{b_1} & \frac{a_{12}}{b_2} & \dots & \frac{a_{1n}}{b_n} \\ \frac{a_{2n}}{b_1} & \frac{a_{22}}{b_2} & & \frac{a_{2n}}{b_n} \\ \dots & \dots & \dots & \dots \\ \frac{a_{n1}}{b_1} & \frac{a_{n2}}{b_2} & \dots & \frac{a_{nn}}{b_n} \end{pmatrix} = \begin{pmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & & g_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ g_{n1} & g_{n2} & \cdots & g_{nn} \end{pmatrix} \quad (5.3.5)$$

By calculating the mean values of the elements of the normalised matrix for all columns of the same row, the elements of the vector of weighting coefficients *w* of dimension *n* are obtained.

$$W = \left(\frac{g_{11} + g_{12} + \cdots g_{1n}}{n}; \quad \frac{g_{21} + g_{22} + \cdots + g_{2n}}{n}; \quad \dots \quad \frac{g_{n1} + g_{n2} + \cdots g_{nn}}{n} \right) = = \frac{\sum_{j=1}^{n} g_{ij}}{n} = w_i, j = 1, n; i = 1, n \quad (5.3.6)$$

The mean value of all elements of the normalised matrix by column represents a vector of weight coefficients (Eqn. (*5.3.6*)), the sum of which is 1. (Eqn. (*5.3.7*))

$$W = \begin{pmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{pmatrix} = \sum_{i=1}^{n} w_i = 1, i = 1, n \quad (5.3.7)$$

The sum of the products of vectors W and B gives the value λ_{max} which represents the maximum eigenvalue $\lambda \sum_{i=1}^{n} w_i \cdot b_{i_{max}}$.

$\boldsymbol{A\omega = \lambda_{max}\omega}$, forms the matrix of preferences, *ω* is the eigenvector of order *n* representing the vector of weight values, while λ_{max} represents the maximum eigenvalue.

The consistency index is calculated according Eqn. (*5.3.8*).

$$\boldsymbol{CI = \frac{\lambda_{max} - n}{n - 1}} \quad (5.3.8)$$

where *n* is the number of parameters (criterion).

The consistency ratio is calculated according to Eqn.(*5.3.9*).

$$\boldsymbol{CR = \frac{CI}{CRI}} \quad (5.3.9)$$

where CRI is the consistency ranking index conditioned by the number of criteria. (Table 12)

Table 12. Consistency ratio for the defined number of criteria

Number of criteria	1	2	3	4	5	6	7	8	9	10
CRI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

When the consistency ratio is less than 10%, it is considered that the relationship between the criteria is consistent, and it is passed to the second stage of the AHP method.

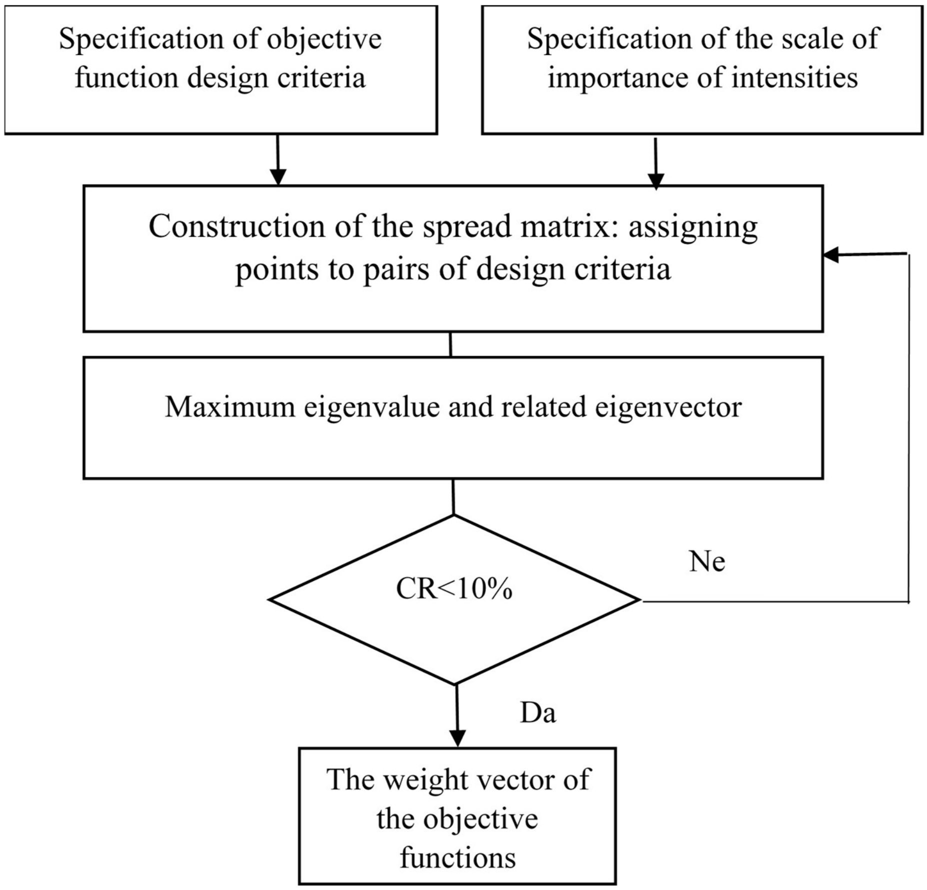


Figure 6. AHP flow diagram

Source: [101]

The selection of the best locations for nautical anchorages was carried out using the AHP method of MCA in the programming language R.[102]

The tools currently available in R for data analysis using the AHP method of MCDM are the packages "*Ahp*" by Glur[103] and "*Prize*" by Dargahi[104] and are excellent tools for performing AHP on a small scale (small number of criteria and variants), and the offers are excellent in terms of interactivity, ease of use and comparing alternatives.[104]

However, researchers who wish to adopt AHP in the analysis of a large number of alternatives often have to manually reformat the data, sometimes even involving dragging and copying across Excel spreadsheets, which is laborious and subject to human error.

There are no good and efficient ways of calculating and visualising heterogeneity when choosing the best solutions using the AHP method in the R language. The inconsistency that often exists when there are a large number of criteria and alternatives makes it impractical in R to identify and correct inconsistent comparisons.

Censoring observations with inconsistency across many variants result in greatly reduced statistical power of the sample or may lead to unrepresentative samples and response bias.

Although AHP serves as an essential tool for making good decisions, helps to get the right direction towards achieving goals, and encourages cooperation with the user, despite its great popularity, it has the significant disadvantage of presenting many pairs of criteria, which makes it quite uncomfortable when the final decision depends on several decision makers.

In the process of selecting the best locations in the case study, the AHP method was applied. AHP implies that after the calculation of the consistency among the criteria, the normalisation of the elements and the calculation of the mean value of the product of the vectors of normalised values of each variant (86 of them - $V_{ij}, j=1,k$) and the vector of weight values (10 or 17 of them - $w_j, j=1,k$), a vector of final values of v_i. (Eqn.(*5.3.10*))

$$v_i = \frac{\prod_{j=1}^{k} V_{ij} w_j}{k} \qquad (5.3.10)$$

A higher value of the variant (v_i) determines a greater influence of the variant on the total rank of the variants (location). The order of variants (location) is sorted by descending impact value, which means that the one with the highest value occupies the first place in the rank (order from best to worst), and so on to the variant with the lowest value and the last position. The AHP procedure and the listing of the R code that was used is shown at the very end in Appendix A.

5.4. TOPSIS

The TOPSIS method was developed by Hwang and Yoon in 1981,[105] and it is based on the idea that the chosen alternative should be the one with the shortest Euclidean distance from the ideal solution and the one with the greatest distance from the negative ideal solution.
An ideal solution is a hypothetical solution for which all attribute values correspond to the maximum values in the data group that includes satisfactory solutions.
A negative ideal solution is a hypothetical solution in which all attribute values correspond to the minimum values in the data group. TOPSIS thus provides a solution that is not only the closest to the hypothetically best solution but also the farthest from the hypothetically worst one.
The TOPSIS method is based on the idea that the optimal variant must have the minimum distance from the ideal solution.
The method entails defining the objective function $f: V \rightarrow R$, given by the Eqn.(*5.4.1*).[105]

$$f(V_i) = \frac{\sum_{j=1}^{n} p_j r_{ij}}{\sum_{j=1}^{n} p_{ij}}, i = 1, m, \qquad (5.4.1)$$

where p_j represents the vector of influence, i.e. the importance of each criterion in the set of criteria n.
The steps of the TOPSIS method are:

- **Step 1.** The normalised matrix $R=(r_{ij}), i=1,...,m, j=1,...,n,$ is built;
- **Step 2.** The weighted normalised matrix $V=(v_{ij}), i=1,...,m, j=1,...,n,$ is built by Eqn.(*5.4.2*), where:

$$v_{ij} = \frac{p_j r_{ij}}{\sum_{j=1}^{n} p_j} \qquad (5.4.2)$$

- **Step 3.** The ideal solutions A, B (Eqn. (*5.4.3*)) defined as in the Eqn. (*5.4.4*) and Eqn. (*5.4.5*) is calculated:

$$A = (a_1, a_2, ..., a_n)$$
$$B = (b_1, b_2, ..., b_n) \qquad (5.4.3)$$

where:

$$a_j = \begin{cases} \underset{1 \leq i \leq m}{max} v_{ij,} if\ C_j\ max \\ \underset{1 \leq i \leq m}{min} v_{ij,}\ if\ C_j\ min \end{cases} \qquad (5.4.4)$$

$$b_j = \begin{cases} \max v_{ij,} \; if \;\; C_j \; min \\ 1 \leq i \leq m \\ \min v_{ij,} \; if \;\; C_j \; max \\ 1 \leq i \leq m \end{cases} \qquad (5.4.5)$$

Step 4. The distances between solutions Eqn. ((5.4.6) and Eqn. ((5.4.7) are calculated:

$$S_i = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - a_j\right)^2} \;, i = 1, m \qquad (5.4.6)$$

$$T_i = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - b_j\right)^2} \;, i = 1, m \qquad (5.4.7)$$

Step 5. The relative proximity from the ideal solution is calculated according to the Eqn. (*5.4.8*):

$$C_i = \frac{T_i}{S_i + T_i} \qquad (5.4.8)$$

Step 6. The classification of the set *V* is performed according to the descending values of C_i obtained in step 5.
The selection of the best solution (selection of 25 out of 86 locations of nautical anchorages) was performed using the TOPSIS technique in the programming language R[105,106] whose code is also R in Appendix A, at the very end of this doctoral dissertation.

5.5. HYBRID AHP-TOPSIS-2N METHOD

The AHP-TOPSIS-2N hybrid method belongs to the group of MCDM methods that combine the AHP and TOPSIS methods with double data normalisation.
AHP-TOPSIS-2N uses part of AHP to calculate criterion weights and uses TOPSIS twice to generate rankings, each time with a different type of normalisation. This enables comparison of results and analysis of robustness. The AHP method calculates the consistency ratio in the first part, and when the consistency ratio is greater than 10%, a verification of the judgment of the criteria relationship is required, the same as with the AHP method.[107]
Considering that AHP is a method for analysing complicated situations and making qualitative decisions,[108] in the AHP-TOPSIS-2N method, the AHP part is responsible for calculating

the vector of weight coefficients for each criterion, using the individual preferences of the of the criteria previously defined by the decision maker.

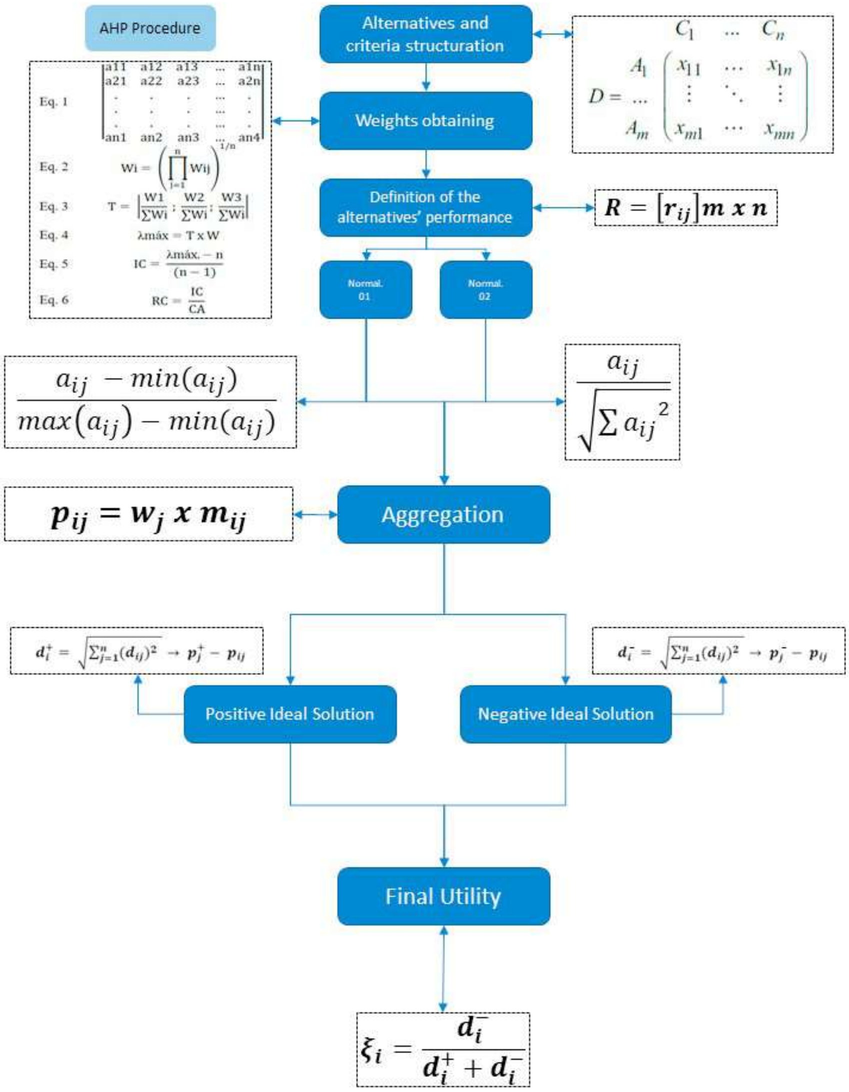


Figure 7. AHP-TOPSIS-2N flow diagram

Source: [107]

In the second part, the TOPSIS method, positions the alternatives according to their distance from the ideal positive solution and the distance from the ideal negative solution.[109]

In the AHP-TOPSIS-2N method, TOPSIS uses double normalisation during the calculation of the value of each alternative based on the vector of weight coefficients (hence the name 2N, "*double normalisation*"). Thus, the AHP-TOPSIS-2N method constitutes an integrated approach between the AHP and TOPSIS methods, where AHP is used for the calculation of criteria weights and TOPSIS for positioning alternatives.

Since the method was used to support decision-making in the computational approach through the R language and the functions of this package, this part of the paper pretends to show the steps behind the program.

To perform AHP-TOPSIS-2N, it is necessary to follow the steps (indicated in the flowchart - Figure 7):[109]

1 - Define alternatives and structure criteria;

2 - Use the AHP method to determine the values weight vector;

3 - Calculation of the value of alternatives;

3.1 - Normalisation process 01;

3.2 - Normalisation process 02;

4 - Aggregation;

5 - Obtaining positive and negative solutions;

5.1 - Analysis of the positive ideal solution;

5.2 - Analysis of the negative ideal solution;

6 - Display of final results and ranking (same as with AHP and TOPSIS methods).

5.6. PROMETHEE II

The PROMETHEE method was developed in the early 1980s and has been extensively studied and refined since then. It has special applications in decision-making and is used worldwide in various decision scenarios, in areas such as business, government institutions, transportation, healthcare and education.[110]

In addition, the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) represents one of the most frequently used MCDM methods. Compared to other methods of MCDM, the PROMETHEE method is a conceptually simple method. The biggest difference between PROMETHEE and other MCDM methods is the establishment of internal comparisons between variants during the decision-making process.[110]

The PROMETHEE method is well suited to decision problems where a finite number of alternatives outweighs the number of multiple conflicting criteria.[111] According to[112] PROMETHEE has several advantages.

The PROMETHEE method of MCDM enables a very detailed presentation of slight and gradual changes or sequences (overtaking) of one variant in relation to another. PROMETHEE's method is applicable to numerous real-life examples and decision-making problems and does not require changes when converting qualitative data into quantitative data.

There are three variants of the method: PROMETHEE I (partial ranking), PROMETHEE II (full ranking), and PROMETHEE III (interval ranking).[113,114]

Considering the complexity of the mutual comparison of all 86 locations (as variants) and the requirements reflected in the comparison of each variant with each (which is almost impossible, due to the number of variants), PROMETHEE I as intended is unacceptable, so it is not used.

PROMETHEE II, however, makes it possible to obtain the final, i.e. complete, order of the variants. The PROMETHEE II method has been widely used in many fields and is available in several different versions.[115] It seems, however, that PROMETHEE II has not yet been fully exploited in a number of scientific fields and research projects.

The PROMETHEE method introduces a preference function to describe the decision maker's preferences between pairs of alternatives for each criterion. In the PROMETHEE method, different preference functions can be defined for the criteria.[116]

For example,[117] used an extended S-shaped preference function to express qualitative criteria such as risk preferences. There are at least six different types of generalised preference functions in the literature. The Type I preference function is the usual criterion. It is a linear dividing function whose range is from 0 to 1, and the limit on the right is zero. Type II is a quasi-criterion, which is almost similar to the usual criterion except that its limit is on the right. Other types of preference functions are type III: linear preference criterion; type IV: level criterion; type V: linear preference and indifference region criterion; and type VI: Gaussian criterion.

All these functions have their own characteristics and are very difficult for the user to understand. The Type VI: Gaussian criterion, for example, is a non-linear function and is definitely different from the Type V: criterion with a linear preference and an indifference region.

Most research nowadays is mainly focused on the combination of these six types of preference functions, rather than on a single preference function. Therefore, a preference is proposed to select the best locations using PROMETHEE II according to the usual type I criterion. However, the effect of PROMETHEE's preference function types on the final preferences, especially in the case of location selection, is not immediately known. There is no general agreement on the choice of preference functions and their effect on the overall ranking.[117]

The computational procedures of PROMETHEE II require several steps,[118] and this doctoral dissertation summarised the same in seven steps.

Therefore, the main procedure of PROMETHEE II is as follows:

Step 1: Determine the criteria (*j =1,…, k*) and the group of possible alternatives in the decision-making problem.

Step 2: Determine/choose weights w_j for different attributes by relative comparison of attributes, in which they show the relative importance/influence of each of the criteria and note that: $\sum_{j=1}^{k} w_j = 1$.

Step 3: Normalise the decision matrix by reducing it to the range *0-1* by applying the Eqn.(*5.5.1*):

$$R_{ij} = \frac{[X_{ij} - \min(X_{ij})]}{[\max(X_{ij}) - \min(X_{ij})]} (i = 1,2,\dots,n \; and \; j = 1,2,\dots m) \qquad (5.5.1)$$

where X_{ij} are the assessment values given by the decision makers $i = 1\dots\dots, n$, and the number of criteria $j = 1,\dots.,m$.

Step 4: Determine the deviations by comparing pairs. $d_j(a,b) = g_j(a) - g_j(b)$ where $d_j(a,b)$ denotes the difference between estimates *a* and *b* on each criterion;

Step 5: Define the preference function $P_j(a,b) = F_j[d_j(a,b)]$, where $P_j(a,b)$ represents the function of the difference between the ratings of alternative *a* compared to alternative *b* for each criterion in a degree in the range of 0 to 1. A smaller number of functions indicates the indifference of the decision maker. On the contrary, the closer it is to 1, the greater the preference.

Step 6: Determine the multi-criteria preference index Eqn. (*5.5.2*)

$$\pi(a,b) = \sum_{j=1}^{k} P(a,b) w_j \qquad (5.5.2)$$

where $w_j > 0$ are the weights associated with each criterion. The symbol $\pi(a, b)$ shows that degree *a* is better than *b* in relation to all criteria.

$\pi(a, b) \approx 0$ implies a weak preference for *a* over *b*.

$\pi(a, b) \approx 1$ implies a strong preference for *a* over *b*.

Step 7: Get the order of preference.

In this step, ranking can be done partially or completely.

A partial ranking can be obtained using PROMETHEE I, and in case a full ranking is required, the calculation must proceed to another step in PROMETHEE II.

(a) Ranking actions by partial ranking (PROMETHEE I).

$$f^{+}(a) = \frac{1}{n-1}\sum_{x\hat{I}A} \pi(a,x)$$
$$f^{-}(a) = \frac{1}{n-1}\sum_{x\hat{I}A} \pi(x,a) \tag{5.5.3}$$

Ranking of actions by partial ranking (PROMETHEE I) is done using Eqn. (*5.5.3*).
The alternative with a higher value of $\phi^{+}(a)$ and a lower value of $\phi^{-}(a)$ is the best alternative.
The preference relationship and partial ranking are performed as follows: Eqn. (*5.5.4*)

$$aP^{+}: \begin{cases} Piff f^{+}(a) \succ ff^{+}(b), \forall a,b \in A \\ Iifff f^{+}(a) = f^{+}(b), \forall a,b \in A \end{cases}$$
$$aP^{-}: \begin{cases} Piff f^{-}(a) \prec f^{-}(b), \forall a,b \in A \\ Iifff f^{-}(a) \succ f^{-}(b), \forall a,b \in A \end{cases} \tag{5.5.4}$$

However, not all alternatives are comparable. Therefore, the net overtaking flow should be calculated in the next step.

(b) Ranking actions according to complete order (PROMETHEE II).

The complete order of alternatives (PROMETHEE II) allows overcoming the problem of incomparability between alternatives by calculating the final rank by the Eqn. (*5.5.5*)

$$f(\mathrm{a}) = f^{+}(\mathrm{a}) - f^{-}(\mathrm{a}) \tag{5.5.5}$$

where $\phi(a)$ denotes the net overtaking flow for each alternative. The preference relationships are as follows:

a outside the lines b $\left(aP^{(II)}b\right)$ $iff\ f(a) \succ f(b), \forall \mathrm{a}, \mathrm{b} \in \mathrm{A}$

a indifferently of b $(aP^{(II)}b)$ $iff\ f(a) = f(b), \forall \mathrm{a}, \mathrm{b} \in \mathrm{A}$

Therefore, all alternatives can be compared based on the value of $\phi(a)$. The highest values of $\phi(a)$ indicate, and the most desirable alternative.

In this series of computational procedures, most steps are fixed except for step 5. The choice of preference functions depends greatly on the characteristics of the criteria and the preferences of decision-makers. Attention is paid to the choice of preference function types, as it may affect the final net overtaking values.

Preference functions

Implementation of the PROMETHEE method requires preference functions. The PROMETHEE preference function defines the trade-off between alternatives for each criterion.[119]

Comparative results

In PROMETHEE it is possible to choose a different preference function for each criterion. Unlike the preference function, the linear preference function with linear preference and indifference region (type V) and the level preference function (type IV) were chosen for the problem of selecting the most suitable twenty-five locations of nautical anchorages in the SDC. The functions are selected based on the criteria. A linear function and a level function are assumed to be adapted to the nature of the criteria by PROMETHEE II. For example, the linear preference function was chosen as one of the functions because it is most suitable for quantitative criteria such as the C6 criterion (number of fields). However, the level preference function is most suitable for qualitative criteria such as the C4 criterion (protection of bays where fields are located). In addition, the level function works well on a few different levels, such as a five-point measurement scale.

The selection of the best locations of nautical anchorages in PROMETHEE II and the numerical representation of the respective importance for each criterion are defined as follows:

The selection of the most suitable locations of nautical anchorages in PROMETHEE II and the numerical representation of the respective importance for each criterion are defined as follows:

The R programming language has six different types of normalisation functions: [1] for normal (0 or 1); [2] for *U-shape (0 or 1) q;* [3] for *V-shape (x/p or 1) p; [4]* for level *(0, 0.5 or 1) q, p;* [5] for V-shape (0, *(x-q)/(p-q) or 1) q, p;* [6] for Gaussian *(0 or 1-e^(-x^2/2*s^2)) s,* where: *q = indifference parameter, p = propensity parameter, s = parameter to indicate the change in the propensity curve.*

For the PROMETHEE II method, the R language code will also be presented.

At the very end of this doctoral dissertation, in the interpretation of the results, the results obtained as AHP, TOPSIS and AHP-TOPSIS+2N will also present those obtained by PROMETHEE II and compared with those obtained through other methods of MCA, on the same group of input data of 86 locations of (possible) nautical anchorages in the area of SDC and based on 10, that is, 17 selected and known criteria, their weight values and each of them with a different goal (maximum or minimum) and the best 25 selected.

5.7. Limitations in the application of MCA methods when selecting the best locations for nautical anchorages

In the process of selecting the spatial locations of nautical anchorages, one should consider some important problems, limitations, and doubts that characterise the multiple goals and numerous stakeholders that appear in this process, as well as some questions that contribute to the description of the complexity of the process of selecting the best locations of nautical anchorages in Split-Dalmatia County.

- Number of possible locations - in SDC there are many potential locations for a nautical anchorage;
- Multiple-contradictory goals require spatial planners to assess the impact of poor infrastructure and/or improper use of nautical anchorages on the environment;
- Intangible goals and/or factors, such as the impact of anchoring on the environment, sea, undersea, coast, flora and fauna, are difficult to quantify, which further complicates the selection methods;
- Diversity of interest groups: Investors or concessionaires are often influenced by various public groups other than their own organisation;
- Impact assessment: Evaluating the impact of each objective and criterion is not always possible or could be a problem. It is not always enough to state that the impact is small, insignificant, considering that it is necessary to express this degree numerically, to compare with other factors;
- Timing of impact: The impact of stakeholder interests in most studies may not occur at the same time and may or may not continue during the life of the concessioned nautical anchorage project;
- Reliability of operation: Uncontrolled and unpredictable natural phenomena such as strong waves, sea currents, storms, floods, earthquakes, and similar phenomena can affect the suitability of the location and add process uncertainties;
- Uncertainty of influence: It is practically impossible to accurately predict all possible influences of all factors that affect nautical anchorage location selection;
- Value trade-offs - Decisions related to value trade-offs, especially among multiple conflicting goals, are a challenge for future decision-makers;
- Delays: Licensing, waiting for the granting of necessary permits and construction are examples of common, unpredictable delays that can significantly affect the economic

viability of the project in the process of selecting the most suitable locations for nautical anchorages;

- Fairness: Determining fairness among all interest groups (users and concessionaires) can be a difficult task involving complex value judgments;
- Uncertainties in government or county management decisions, or spatial planners;
- Procedures of state and administrative bodies can have a significant influence on the relative recommendation in the selection of certain locations of nautical anchorages in the group of possible over time;
- AHP is applicable to a maximum of ten criteria. Thus, to apply the AHP and AHP-TOPSIS-2N methods, from the available data for 86 locations of nautical anchorages and 17 selection criteria, the ten most important ones were selected, while in other methods of MCA (TOPSIS and PROMETHEE II), all 17 known criteria were taken for each location;
- Stakeholder views on risk: Determination, and compilation of stakeholder views on risk as utility functions are important for the proper selection of the most suitable locations.

6. DATA ANALYSIS, RESULTS

6.1. Description of input data

In the fourth chapter of this doctoral dissertation, in chapter 4.1, after the description of the most important criteria and recommendations related to nautical anchorages, according to the opinions of experts, the results of the survey research that represent the attitudes and opinions of users are presented and analysed in detail. The ratings represent the degree of importance of all criteria on which sailors expressed their views in the survey.

Based on the ratings of users, sailors in the survey, certain weighting values were assigned to the selected criteria so that, based on them as well as on the basis of data on variants representing the locations of nautical anchorages, MCDM methods could be applied.

The second phase of the research involves the application of MCA methods (AHP, TOPSIS; hybrid AHP-TOPSIS-2N and PROMETHEE II) using input data obtained as a result of diligent collection, storage, analysis and processing of many years of work and experience and refers to a group of fifty-six (Table 13) detailed descriptions of possible locations of nautical anchorages in the area of SDC.

As part of this doctoral dissertation, the author of this research has published a scientific paper titled "*Multi-Criteria Decision Analysis for Nautical Anchorage Selection*" Th.is work was published in the esteemed Journal of Marine Science and Engineering in the year 2023[120] The publication showcases the findings and outcomes of the research phase, providing valuable insights into the subject matter. The work demonstrates the application of multi-criteria decision analysis in the selection process of nautical anchorages in SDC, as shown in Figures 8-15. This research contributes to the field of marine science and engineering by offering a systematic approach to anchor selection, considering various criteria and factors. The accuracy, reliability and credibility of the methods used were confirmed by publication in a high-ranking journal.

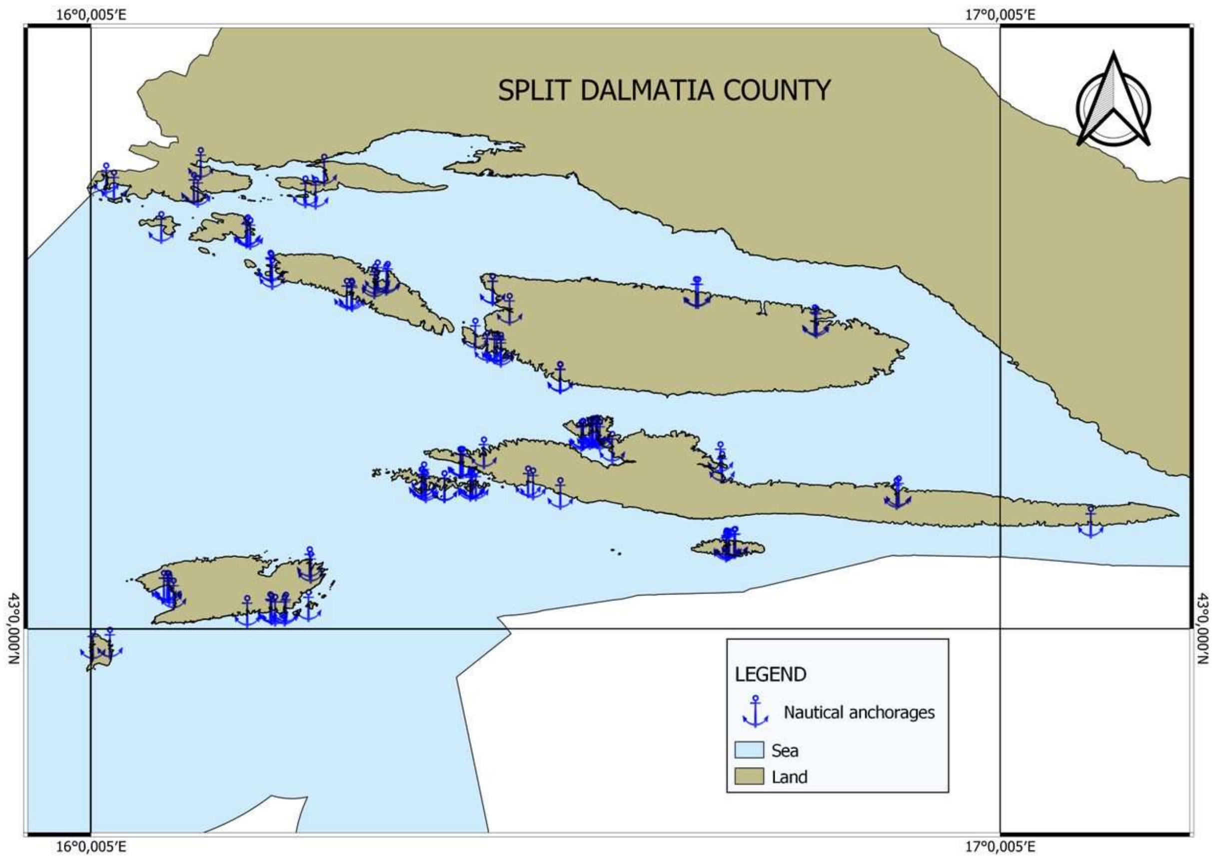


Figure 8. Spatial distribution of nautical anchorages in the area of SDC

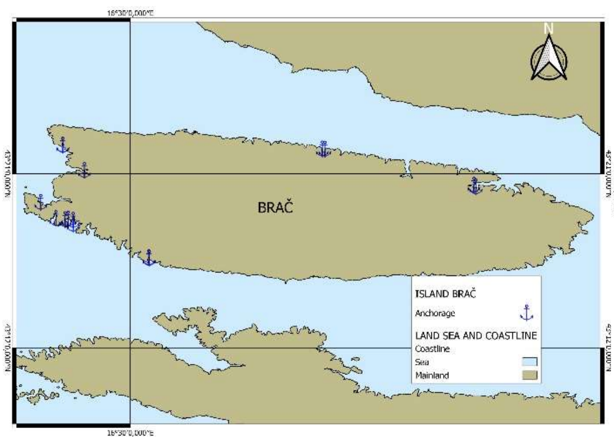


Figure 9. Spatial representation of nautical anchorages on Brač Island

Source: [Author]

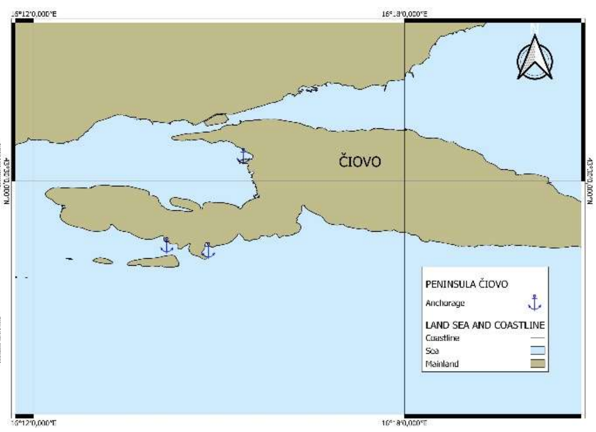


Figure 10. Spatial representation of nautical anchorages on Čiovo Island

Source: [Author]

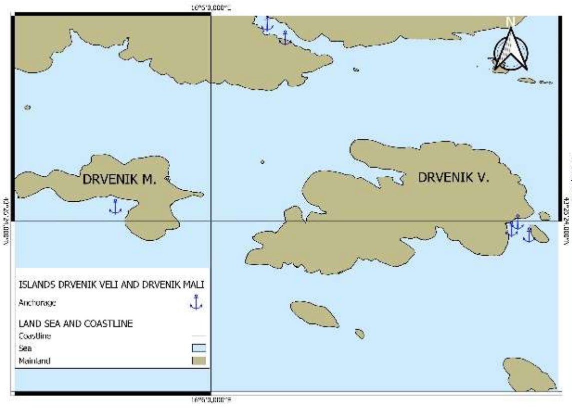


Figure 11. Spatial representation of nautical anchorages on Drvenik Island

Source: [Author]

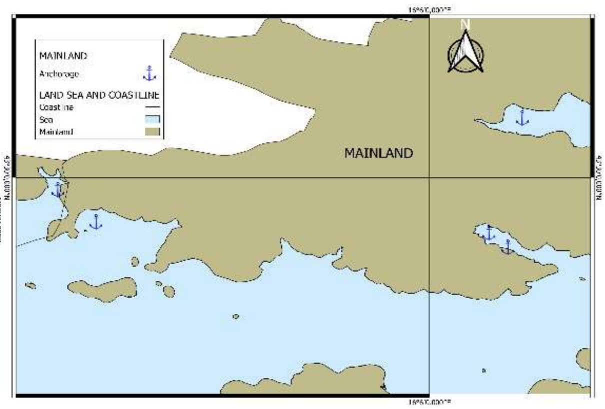


Figure 12. Spatial representation of nautical anchorages on the mainland

Source: [Author]

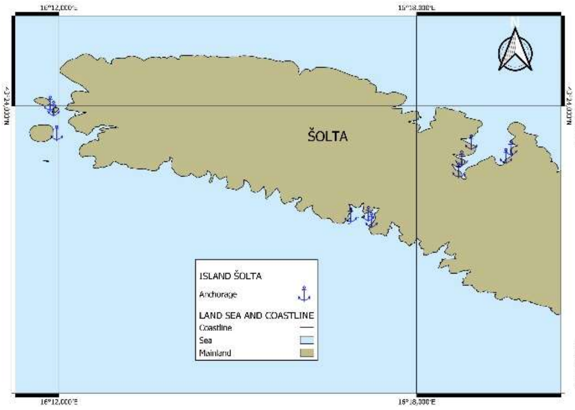


Figure 13. Spatial representation of nautical anchorages on Šolta Island

Source: [Author]

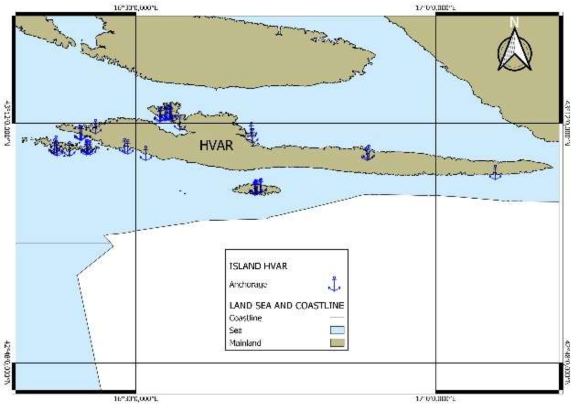


Figure 14. Spatial representation of nautical anchorages on Hvar Island

Source: [Author]

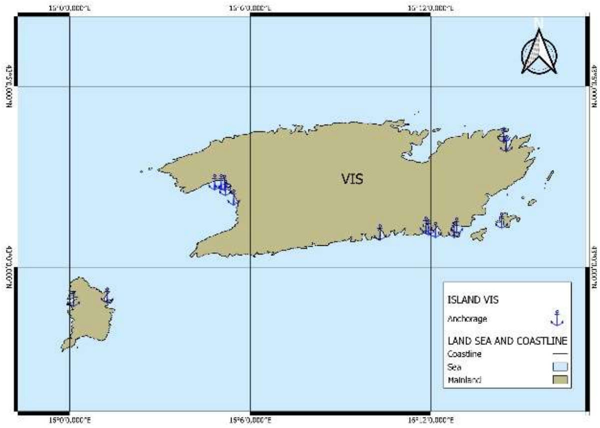


Figure 15. Spatial representation of nautical anchorages on Vis Island

Source: [Author]

Table 13. Names of locations, names of islands, field marks and the locations of nautical anchorages in the area of SDC

No	Name	Location	Field/s
1	MILNA Lučice	BRAČ Island	A, B, C
2	MILNA Mali bok	BRAČ Island	A
3	MILNA Osibova uvala	BRAČ Island	A
4	MILNA Uvala Slavinjina	BRAČ Island	A
5	NEREŽIŠĆA Uvala Blaca	BRAČ Island	A, B
6	PUČIŠĆA Luka Pučišće	BRAČ Island	A, B
7	POSTIRA Uvala Lovrečina	BRAČ Island	A, B
8	SUTIVAN Uvala Vića	BRAČ Island	A
9	SUTIVAN Uvala Stipanska	BRAČ Island	A
10	MARINA Uvala Miline - Eastern coast Oštrica mala	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
11	OKRUG GORNJI Uvala Sveta Fumija	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A, B
12	OKRUG GORNJI Uvala Pirčina	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
13	ŠOLTA Uvala Nečujam - Uvala Šumpjevina	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
14	ŠOLTA Uvala Nečujam - Uvala Potkamenica	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
15	ŠOLTA Uvala Nečujam - Mala Maslinica	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
16	ŠOLTA Uvala Nečujam - Uvala Supetar	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
17	ŠOLTA Uvala Nečujam - Tiha uvala	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
18	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A, B, C

19	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A, B
20	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A, B, C
21	OKRUG GORNJI Uvala Duboka	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
22	OKRUG GORNJI Zaljev Saldun, Punta Rožac	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
23	DRVENIK MALI Uvala Vela Rina	ČIOVO, DRVENIK, ŠOLTA islands AND MAINLAND	A
24	HVAR Luka Soline - Uvala Prevojice	HVAR Island	A, B
25	HVAR Luka Soline - western part	HVAR Island	A
26	HVAR Stipanska uvala	HVAR Island	A, B
27	HVAR Uvala Taršće	HVAR Island	A, B
28	HVAR Uvala Vinogradišće	HVAR Island	A, B
29	HVAR Ždrilica	HVAR Island	A, B, C, D
30	HVAR Uvala Mala Milna	HVAR Island	A
31	HVAR Vela Garška uvala	HVAR Island	A, B, C
32	JELSA Luka Lovišće	HVAR Island	A, B, C, D
33	JELSA Uvala Moster	HVAR Island	A, B
34	Uvala Tiha - Malo Stupišće	HVAR Island	A
35	Uvala Tiha - Veliko Stupišće	HVAR Island	A, B
36	Uvala Tiha - Vučja	HVAR Island	A
37	Uvala Tiha - Mitki bok	HVAR Island	A, B
38	Uvala Tiha - Veli Dolac	HVAR Island	A, B
39	Uvala Tiha - Paklena	HVAR Island	A
40	JELSA Soline Vrboska	HVAR Island	A
41	JELSA Uvala Pokrvenik	HVAR Island	A, B
42	STARI GRAD Uvala Hobonj	HVAR Island	A
43	STARI GRAD Zavala	HVAR Island	A
44	SUĆURAJ Luka Mrtinovik	HVAR Island	A
45	HVAR Uvala Vlaka, Pakleni otoci	HVAR Island	A
46	HVAR Uvala V. Zaraće	HVAR Island	A
47	HVAR Uvala Pribinja	HVAR Island	A
48	KOMIŽA Uvala Mezuporat	VIS Island	A
49	VIS Budikovac	VIS Island	A

50	VIS Uvala Stončica	VIS Island	A
51	VIS Uvala Stončica - Uvala Vela Čavojnica	VIS Island	A
52	KOMIŽA Biševska luka	VIS Island	A
53	VIS Rukavac	VIS Island	A, B
54	VIS Srebrna	VIS Island	A
55	VIS Uvala Stiniva	VIS Island	A
56	VIS Uvala Ruda	VIS Island	A, B

Since some locations include more than one field, a location with multiple fields is considered separately for each field, independent locations. This is how Table 14 was created, which contains data on eighty-six locations.

Table 14. Detailed presentation of input data on the locations of nautical anchorages in the area of SDC

No.	Name	Island	Field	SurfaceF	SurfaceB	Percentage	Protection	Distance	NumberF
1	MILNA Lučice	BRAČ	A	2,059.39	723,767.14	0.3	partially protected	3.9	3
2	MILNA Lučice	BRAČ	B	17,781.05	723,767.14	2.5	partially protected	24.3	3
3	MILNA Lučice	BRAČ	C	6,744.95	723,767.14	0.9	partially protected	24.0	3
4	MILNA Mali bok	BRAČ	A	3,416.15	11,800.58	28.9	unprotected	12.4	1
5	MILNA Osibova uvala	BRAČ	A	5,176.56	227,733.31	2.3	partially protected	2.7	1
6	MILNA Uvala Slavinjina	BRAČ	A	7,756.37	64,415.18	12.0	partially protected	15.2	1
7	NEREŽIŠĆA Uvala Blaca	BRAČ	A	5,990.29	71,424.38	8.4	partially protected	15.8	2
8	NEREŽIŠĆA Uvala Blaca	BRAČ	B	2,400.00	71,424.38	3.4	partially protected	0.0	2
9	PUČIŠĆA Luka Pučišće	BRAČ	A	12,634.41	153,538.63	8.2	protected	4.4	2
10	PUČIŠĆA Luka Pučišće	BRAČ	B	9,900.11	153,538.63	6.4	protected	13.1	2
11	POSTIRA Uvala Lovrečina	BRAČ	A	15,056.05	100,294.43	15.0	unprotected	7.4	2
12	POSTIRA Uvala Lovrečina	BRAČ	B	13,771.01	100,294.43	13.7	unprotected	14.4	2
13	SUTIVAN Uvala Vića	BRAČ	A	5,495.04	31,664.56	17.4	protected	4.6	1
14	SUTIVAN Uvala Stipanska	BRAČ	A	3,457.25	46,398.67	7.5	unprotected	11.9	1
15	MARINA Uvala Miline - Eastern coast Oštrica mala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	73,429.68	438,906.63	16.7	protected	81.2	1
16	OKRUG GORNJI Uvala Sveta Fumija	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	4,792.32	641,244.47	0.7	protected	37.4	2

17	OKRUG GORNJI Uvala Sveta Fumija	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	16,925.83	641,244.47	2.6	protected	26.3	2
18	OKRUG GORNJI Uvala Pirčina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	5,997.74	22,357.42	26.8	partially protected	6.6	1
19	ŠOLTA Uvala Nečujam - Uvala Šumpjevina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	8,020.14	63,252.47	12.7	partially protected	9.6	1
20	ŠOLTA Uvala Nečujam - Uvala Potkamenica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	3,842.70	23,054.82	16.7	partially protected	8.7	1
21	ŠOLTA Uvala Nečujam - Mala Maslinica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	5,951.07	46,591.92	12.8	partially protected	27	1
22	ŠOLTA Uvala Nečujam - Uvala Supetar	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	9,962.35	92,965.25	10.7	partially protected	48.5	1
23	ŠOLTA Uvala Nečujam - Tiha uvala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	3,893.59	14,370.81	27.1	partially protected	21.4	1
24	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	7,561.37	368,850.39	2.0	partially protected	50.2	3
25	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	7,561.51	368,850.39	2.1	partially protected	42.4	3
26	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	C	12,031.56	368,850.39	3.3	partially protected	24.8	3
27	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	9,797.21	381,807.85	2.6	protected	11.4	2
28	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	19,119.20	381,807.85	5.0	protected	60.9	2
29	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	4,967.51	365,276.02	1.4	partially protected	13.4	3
30	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	11,327.23	365,276.02	3.1	partially protected	14.8	3
31	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	C	5,369.64	365,276.02	1.5	partially protected	5.8	3
32	OKRUG GORNJI Uvala Duboka	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	18,908.51	64,407.48	29.4	unprotected	48.4	1
33	OKRUG GORNJI Zaljev Saldun, Punta Rožac	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	16,416.96	83,076.61	19.8	partially protected	44.9	1

34	DRVENIK MALI Uvala Vela Rina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	76,654.37	339,484.25	22.6	unprotected	76.5	1
35	HVAR Luka Soline - Uvala Prevojice	HVAR	A	12,189.12	158,135.45	7.7	partially protected	18.1	2
36	HVAR Luka Soline - Uvala Prevojice	HVAR	B	29,040.95	158,135.45	18.4	partially protected	9.8	2
37	HVAR Luka Soline - western part	HVAR	A	18,809.22	55,958.72	33.6	partially protected	10.5	1
38	HVAR Stipanska uvala	HVAR	A	28,014.56	129,531.52	21.6	partially protected	11.9	2
39	HVAR Stipanska uvala	HVAR	B	5,653.71	129,531.52	4.4	partially protected	4.7	2
40	HVAR Uvala Taršće	HVAR	A	19,045.87	270,860.78	7.0	protected	7	2
41	HVAR Uvala Taršće	HVAR	B	39,759.11	270,860.78	14.7	protected	5.2	2
42	HVAR Uvala Vinogradišće	HVAR	A	33,300.56	172,777.22	19.3	protected	15.6	2
43	HVAR Uvala Vinogradišće	HVAR	B	20,184.50	172,777.22	11.7	protected	6.2	2
44	HVAR Ždrilica	HVAR	A	15,461.52	232,623.14	6.6	protected	27.1	4
45	HVAR Ždrilica	HVAR	B	19,223.69	232,623.14	8.3	protected	29.2	4
46	HVAR Ždrilica	HVAR	C	11,217.76	232,623.14	4.8	protected	7.4	4
47	HVAR Ždrilica	HVAR	D	4,294.60	232,623.14	1.8	protected	8.2	4
48	HVAR Uvala Mala Milna	HVAR	A	9,019.93	42,964.85	21.0	unprotected	38.7	1
49	HVAR Vela Garška uvala	HVAR	A	4,173.73	89,446.05	4.7	partially protected	11.9	3
50	HVAR Vela Garška uvala	HVAR	B	2,048.41	89,446.05	2.3	partially protected	18.7	3
51	HVAR Vela Garška uvala	HVAR	C	5,841.32	89,446.05	6.5	partially protected	10.2	3
52	JELSA Luka Lovišće	HVAR	A	8,387.75	143,621.11	5.8	partially protected	5.7	4
53	JELSA Luka Lovišće	HVAR	B	5,235.86	143,621.11	3.6	partially protected	8.6	4
54	JELSA Luka Lovišće	HVAR	C	3,112.82	143,621.11	2.2	partially protected	6.2	4
55	JELSA Luka Lovišće	HVAR	D	7,322.86	143,621.11	5.1	partially protected	6.4	4
56	JELSA Uvala Moster	HVAR	A	4,663.32	63,348.89	7.4	partially protected	5.9	2
57	JELSA Uvala Moster	HVAR	B	5,908.71	63,348.89	9.3	partially protected	3.1	2
58	Uvala Tiha - Malo Stupišće	HVAR	A	1,585.75	17,635.17	9.0	unprotected	19.2	1
59	Uvala Tiha - Veliko Stupišće	HVAR	A	1,649.94	24,401.10	6.8	unprotected	21.6	2
60	Uvala Tiha - Veliko Stupišće	HVAR	B	2,601.84	24,401.10	10.7	unprotected	9.1	2
61	Uvala Tiha - Vucja	HVAR	A	2,793.77	32,982.85	8.5	partially protected	21.8	1
62	Uvala Tiha - Mitki bok	HVAR	A	2,998.57	68,871.31	4.4	partially protected	31	2
63	Uvala Tiha - Mitki bok	HVAR	B	3,301.45	68,871.31	4.8	partially protected	42.7	2
64	Uvala Tiha - Veli Dolac	HVAR	A	9,075.05	43,204.52	21.0	partially protected	9.7	2

65	Uvala Tiha - Veli Dolac	HVAR	B	2,204.46	43,204.52	5.1	partially protected	15.6	2
66	Uvala Tiha - Paklena	HVAR	A	2,911.78	26,374.64	11.0	partially protected	10.5	1
67	JELSA Soline Vrboska	HVAR	A	21,759.24	215,264.65	10.1	unprotected	13.5	1
68	JELSA Uvala Pokrvenik	HVAR	A	6,947.12	96,286.36	7.2	protected	9.6	2
69	JELSA Uvala Pokrvenik	HVAR	B	900.00	96,286.36	0.9	protected	8.1	2
70	STARI GRAD Uvala Hobonj	HVAR	A	3,540.92	19,984.43	17.7	partially protected	4.4	1
71	STARI GRAD Zavala	HVAR	A	3,950.60	89,259.53	4.4	protected	7.8	1
72	SUĆURAJ Luka Mrtinovik	HVAR	A	3,698.50	130,729.53	2.8	partially protected	10.5	1
73	HVAR Uvala Vlaka, Pakleni otoci	HVAR	A	17,977.06	192,140.53	9.4	unprotected	24.5	1
74	HVAR Uvala V. Zaraće	HVAR	A	16,066.28	75,178.13	21.4	partially protected	23.2	1
75	HVAR Uvala Pribinja	HVAR	A	22,435.02	124,493.66	18.0	protected	50.9	1
76	KOMIŽA Uvala Mezuporat	VIS	A	5,929.95	79,469.29	7.5	unprotected	27.2	1
77	VIS Budikovac	VIS	A	19,034.87	48,094.56	39.6	unprotected	8.7	1
78	VIS Uvala Stončica	VIS	A	22,354.01	190,158.53	11.8	protected	8.1	1
79	VIS Uvala Stončica - Uvala Vela Čavojnica	VIS	A	13,268.09	77,017.13	17.2	protected	12.3	1
80	KOMIŽA Biševska luka	VIS	A	9,156.65	98,277.88	9.3	protected	20	1
81	VIS Rukavac	VIS	A	8,473.78	140,579.16	6.0	partially protected	21.9	2
82	VIS Rukavac	VIS	B	4,936.84	140,579.16	3.5	partially protected	3.1	2
83	VIS Srebrna	VIS	A	10,809.48	50,893.55	21.2	partially protected	14	1
84	VIS Uvala Stiniva	VIS	A	7,897.21	95,881.30	8.2	partially protected	1.9	1
85	VIS Uvala Ruda	VIS	A	4,375.82	91,277.43	4.8	protected	12.3	2
86	VIS Uvala Ruda	VIS	B	6,871.98	91,277.43	7.5	protected	11	2

The case study takes as input data (Table 14) as follows by column:

1. Serial number of the location;
2. Name of the future (possible) location of the nautical anchorage;
3. Name of the island or geographical area of SDC where the anchorage is located;
4. Field name (A, B, C, D, E, ...);
5. Area of the field of the future anchorage in square meters;
6. Area of the cove in square meters;
7. The share of the field area in relation to the bay area in percentages;
8. Degree of protection (unprotected; partially protected; protected);
9. Distance from the coast in meters;
10. Number of fields at that location, including the field being analysed;
11. Existence of maritime traffic (If the proximity of the main traffic routes is less than

500 1 - Yes; 5 - No);

12. Existence of an official anchorage (1 - Yes; 5 - No);
13. Existence of underwater cables and pipelines (Proximity of cables and pipelines less than 500 m; 1 - Yes, 5 - No);
14. Risk of collision (1 - negligible; 2 - small; 3 - medium; 4 - large; 5 - very high);
15. Depth (1 - Satisfactory; 5 - Unsatisfactory);
16. Tide level and existence of sea currents (1 - small; 3 - medium; 5 - large);
17. Proximity to the public ports (1 - No; 5 - Yes);
18. Proximity to the existing berths (1 - No; 5 - Yes);
19. Environmental elements (Environmental network Natura 2000, 1 - No; 5 - Yes);
20. Harm from anchoring a vessel to the holding ground (1 - No; 5 - Yes)
21. Archaeological sites (1 - No; 5 - Yes)

The depth of the sea, item 15 from the previous list, determines the minimum depth for anchoring a vessel, which depends on the size of the vessel that can access the anchorage. The minimum requirement for the construction of a nautical anchorage is the depth required for launching a vessel. It goes without saying that the sea depth of the nautical anchorage is between two and six meters. Given that all analysed fields, 86 of them, meet the conditions regarding sea depth for safe navigation and anchoring, the factor of sea depth as a criterion when applying AHP and the hybrid AHP-TOPSIS-2N method was not taken as an important criterion when applying these two methods, given that these methods allow a maximum of 10 criteria. However, depth was taken as one of the seventeen other criteria for which there is available data in the TOPSIS and PROMETHEE II methods, given that both allow the number of criteria to be greater than 10.

Aggregate data by group (islands and mainland), for all locations is given in the table below. (Table 15)

Table 15. Location data - sum, mean, minimum, maximum: field surface, bay surface, percentage (%) share of field surface in relation to bay surface, distance from the coast (m) and number of fields in the locations

Island	SUM/MEAN/TOTAL	SurfaceF	SurfaceB	Percentage	Protection	Distance	NumberF
BRAČ	SUM	111,638.63	3,203,828.58	126.91	**4**	154.10	26
	MEAN	16,126.52	228,844.90	9.06	**7**	11.01	1.86
	TOTAL	**14**	**14**	**14**	**3**	**14**	**14**
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	SUM	322,530.49	5,436,951.53	219.44	**2**	660.20	36
	MEAN	16,126.52	271,847.58	10.97	**13**	33.01	1.80
	TOTAL	**20**	**20**	**20**	**5**	**20**	**20**

HVAR	SUM	438,307.23	4,851,116.14	401.01	**6**	610.00	89
	MEAN	10,690.42	118,319.91	9.78	**23**	14.88	2.17
	TOTAL	**41**	**41**	**41**	**12**	**41**	**41**
VIS	SUM	113,108.68	1,103,505.42	136.68	**2**	140.50	15
	MEAN	10,282.61	100,318.67	12.43	**4**	12.77	1.36
	TOTAL	**11**	**11**	**11**	**5**	**11**	**11**
	SUM	985,585.03	14,595,401.67	884.03	**14**	1,564.80	166
	MEAN	11,460.29	169,713.97	10.28	**47**	18.20	1.93
	TOTAL	**86**	**86**	**86**	**25**	**86**	**86**
	MIN	900.00	11,800.58	0.28		0.00	1
	MAX	76,654.37	723,767.14	39.58		81.20	4

Note: In the column "**protection**" in Table 15, the first row (the blue field of the table) represents the number of unprotected bays; the orange field of the table in the second row represents the number of partially protected bays; and the third row (the yellow field of the table) represents the number of protected bays.

Table 16. Summary data of all analysed locations on the degree of protection from wind, waves, and sea currents

Protection of the bay of the nautical anchorage	**Number**
Unprotected	14
Partially protected	47
Protected	25
Total / Number	**86**

The following provides a detailed presentation of all input data by islands and/or geographical area of SDC.

Table 17 presents individual data for the locations of nautical anchorages on Brač Island.

Table 17. Data on the locations of nautical anchorages on Brač Island

No	Name	Island	Field	surfaceF	surfaceB	percentage	protection	distance	numberF
1	MILNA Lučice	BRAČ	A	2,059.39	723,767.14	0.3	partially protected	3.9	3
2	MILNA Lučice	BRAČ	B	17,781.05	723,767.14	2.5	partially protected	24.3	3
3	MILNA Lučice	BRAČ	C	6,744.95	723,767.14	0.9	partially protected	24.0	3
4	MILNA Mali bok	BRAČ	A	3,416.15	11,800.58	28.9	unprotected	12.4	1
5	MILNA Osibova uvala	BRAČ	A	5,176.56	227,733.31	2.3	partially protected	2.7	1
6	MILNA Uvala Slavinjina	BRAČ	A	7,756.37	64,415.18	12.0	partially protected	15.2	1
7	NEREŽIŠĆA Uvala Blaca	BRAČ	A	5,990.29	71,424.38	8.4	partially protected	15.8	2
8	NEREŽIŠĆA Uvala Blaca	BRAČ	B	2,400.00	71,424.38	3.4	partially protected	0.0	2
9	PUČIŠĆA Luka Pučišće	BRAČ	A	12,634.41	153,538.63	8.2	protected	4.4	2
10	PUČIŠĆA Luka Pučišće	BRAČ	B	9,900.11	153,538.63	6.4	protected	13.1	2
11	POSTIRA Uvala Lovrečina	BRAČ	A	15,056.05	100,294.43	15.0	unprotected	7.4	2
12	POSTIRA Uvala Lovrečina	BRAČ	B	13,771.01	100,294.43	13.7	unprotected	14.4	2
13	SUTIVAN Uvala Vića	BRAČ	A	5,495.04	31,664.56	17.4	protected	4.6	1
14	SUTIVAN Uvala Stipanska	BRAČ	A	3,457.25	46,398.67	7.5	unprotected	11.9	1
			Sum	**111,638.63**	**3,203,828.58**	**126.9**		**154.1**	**26.0**
			Mean	**7,974.19**	**228,844.90**	**9.1**	**3 protected**	**11.0**	**1.9**
			Min	**2,059.39**	**11,800.58**	**0.3**	**7 partially protected**	**0.0**	**1.0**
			Max	**17,781.05**	**723,767.14**	**28.9**	**4 unprotected**	**24.3**	**3.0**

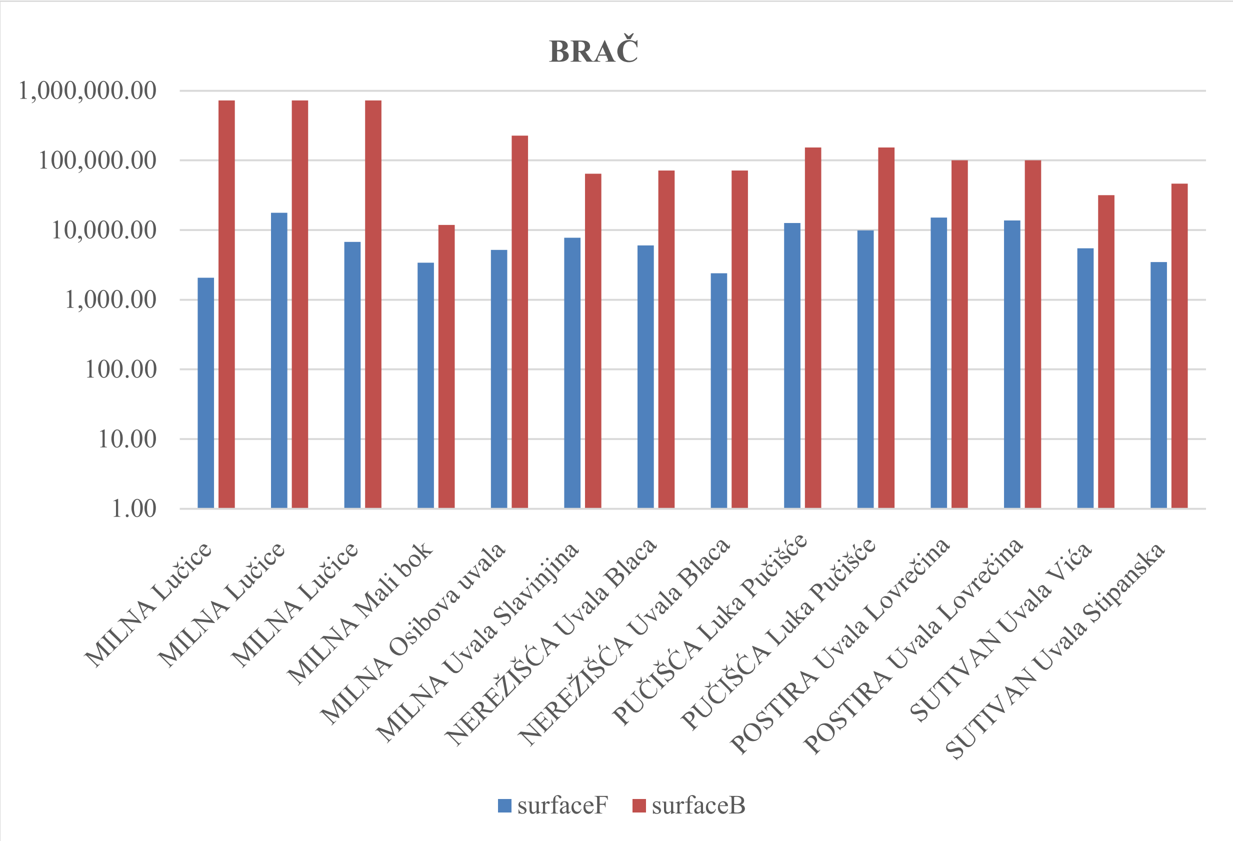


Chart 4. The ratio of the field surface in relation to the surface of the bays on Brač Island in the logarithmic scale

Chart 4. graphically shows the relationship between the surface of the fields compared to the surface of the bays for all locations, the fields on the Island of Brač.

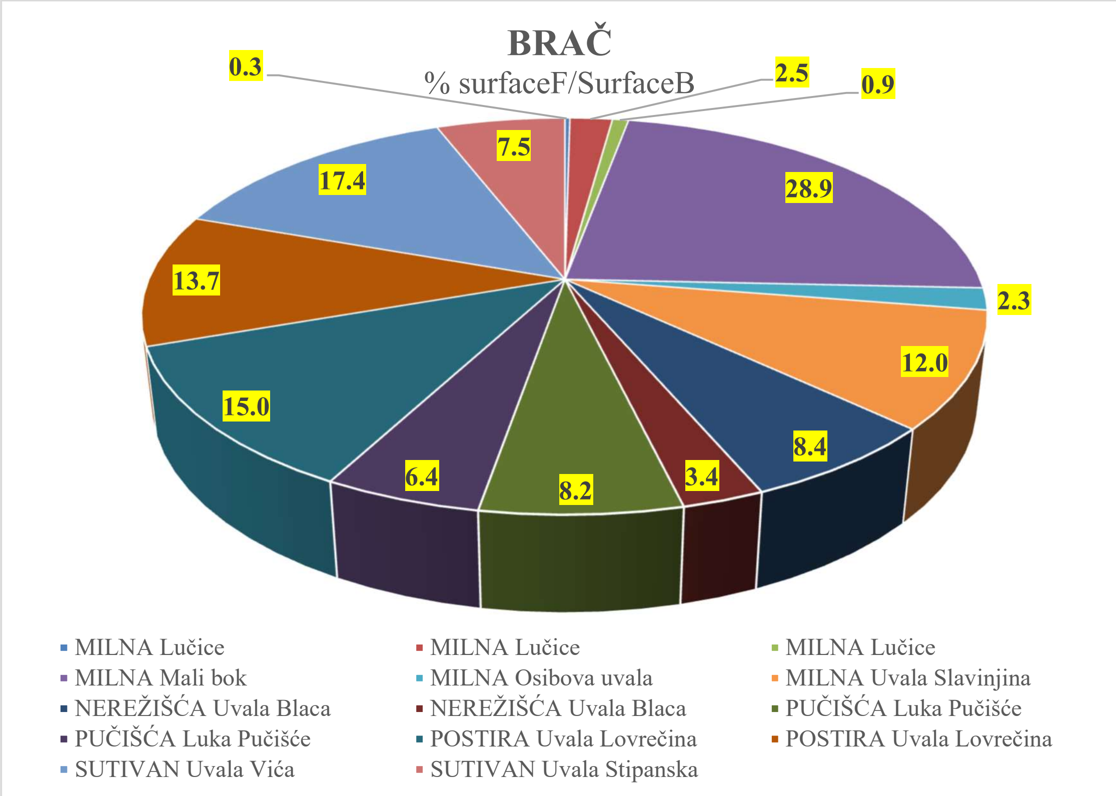


Chart 5. The share of the field surface in relation to the surface of the bays on Brač Island in percentages

Chart 5 shows graphically the percentage of field surface in relation to the surface of bays on Brač Island.

Table 18 contains individual data on the location of nautical anchorages on the islands of Čiovo, Drvenik, Šolta and the mainland.

Table 18. Information on the locations of nautical anchorages in Čiovo, Drvenik, Šolta islands and on the mainland

No	Name	Island	Field	surfaceF	surfaceB	percentage	protection	distance	numberF
1	MARINA Uvala Miline - Eastern coast of Oštrica mala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	73,429.68	438,906.63	16.7	protected	81.2	1
2	OKRUG GORNJI Uvala Sveta Fumija	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	4,792.32	641,244.47	0.7	protected	37.4	2
3	OKRUG GORNJI Uvala Sveta Fumija	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	16,925.83	641,244.47	2.6	protected	26.3	2
4	OKRUG GORNJI Uvala Pirčina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	5,997.74	22,357.42	26.8	partially protected	6.6	1
5	ŠOLTA Uvala Nečujam - Uvala Šumpjevina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	8,020.14	63,252.47	12.7	partially protected	9.6	1
6	ŠOLTA Uvala Nečujam - Uvala Potkamenica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	3,842.70	23,054.82	16.7	partially protected	8.7	1
7	ŠOLTA Uvala Nečujam - Mala Maslinica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	5,951.07	46,591.92	12.8	partially protected	27	1
8	ŠOLTA Uvala Nečujam - Uvala Supetar	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	9,962.35	92,965.25	10.7	partially protected	48.5	1
9	ŠOLTA Uvala Nečujam - Tiha uvala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	3,893.59	14,370.81	27.1	partially protected	21.4	1
10	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	7,561.37	368,850.39	2.0	partially protected	50.2	3
11	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	7,561.51	368,850.39	2.1	partially protected	42.4	3
12	TROGIR Uvala Krknjaš	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	C	12,031.56	368,850.39	3.3	partially protected	24.8	3
13	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	9,797.21	381,807.85	2.6	protected	11.4	2
14	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	19,119.20	381,807.85	5.0	protected	60.9	2
15	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	4,967.51	365,276.02	1.4	partially protected	13.4	3
16	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	B	11,327.23	365,276.02	3.1	partially protected	14.8	3
17	ŠOLTA Uvala Tatinja	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	C	5,369.64	365,276.02	1.5	partially protected	5.8	3
18	OKRUG GORNJI Uvala Duboka	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	18,908.51	64,407.48	29.4	unprotected	48.4	1
19	OKRUG GORNJI Zaljev Saldun, Punta Rožac	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	16,416.96	83,076.61	19.8	partially protected	44.9	1
20	DRVENIK MALI Uvala Vela Rina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	A	76,654.37	339,484.25	22.6	unprotected	76.5	1
		Sum		**322,530.49**	**5,436,951.53**	**219.4**		**660.2**	**36**
		Mean		**16,126.52**	**271,847.58**	**11.0**	**5 protected**	**33.0**	**1.8**
		Min		**3,842.70**	**14,370.81**	**0.7**	**13 partially protected**	**5.8**	**1**
		Max		**641,244.47**	**641,244.47**	**29.4**	**2 unprotected**	**81.2**	**3**

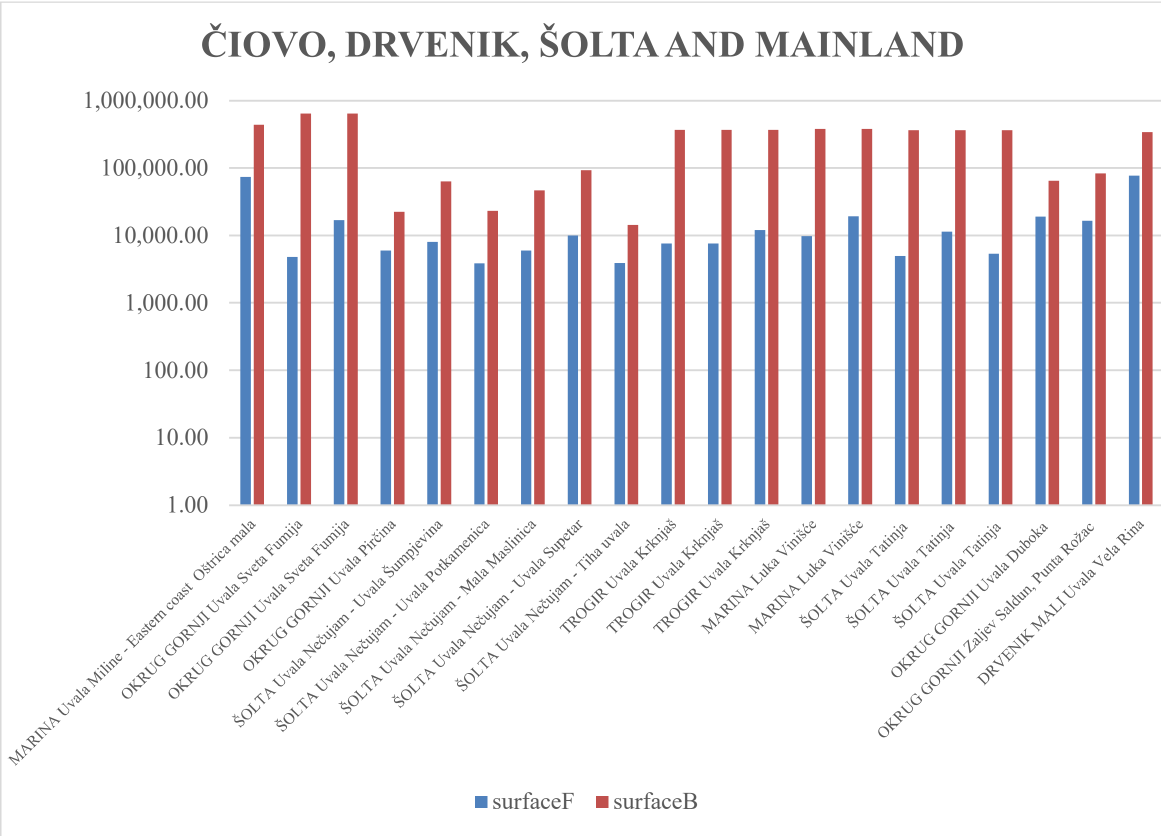


Chart 6. Graphic representation of the share of the field surface in relation to the surface of the bay on the islands Čiovo, Drvenik, Šolta, and mainland on logarithmic scale

Chart 7 graphically shows the share of the field surface in the total surface of the bay at all locations of nautical anchorages in Čiovo, Drvenik, Šolta islands, and the mainland in percentage.

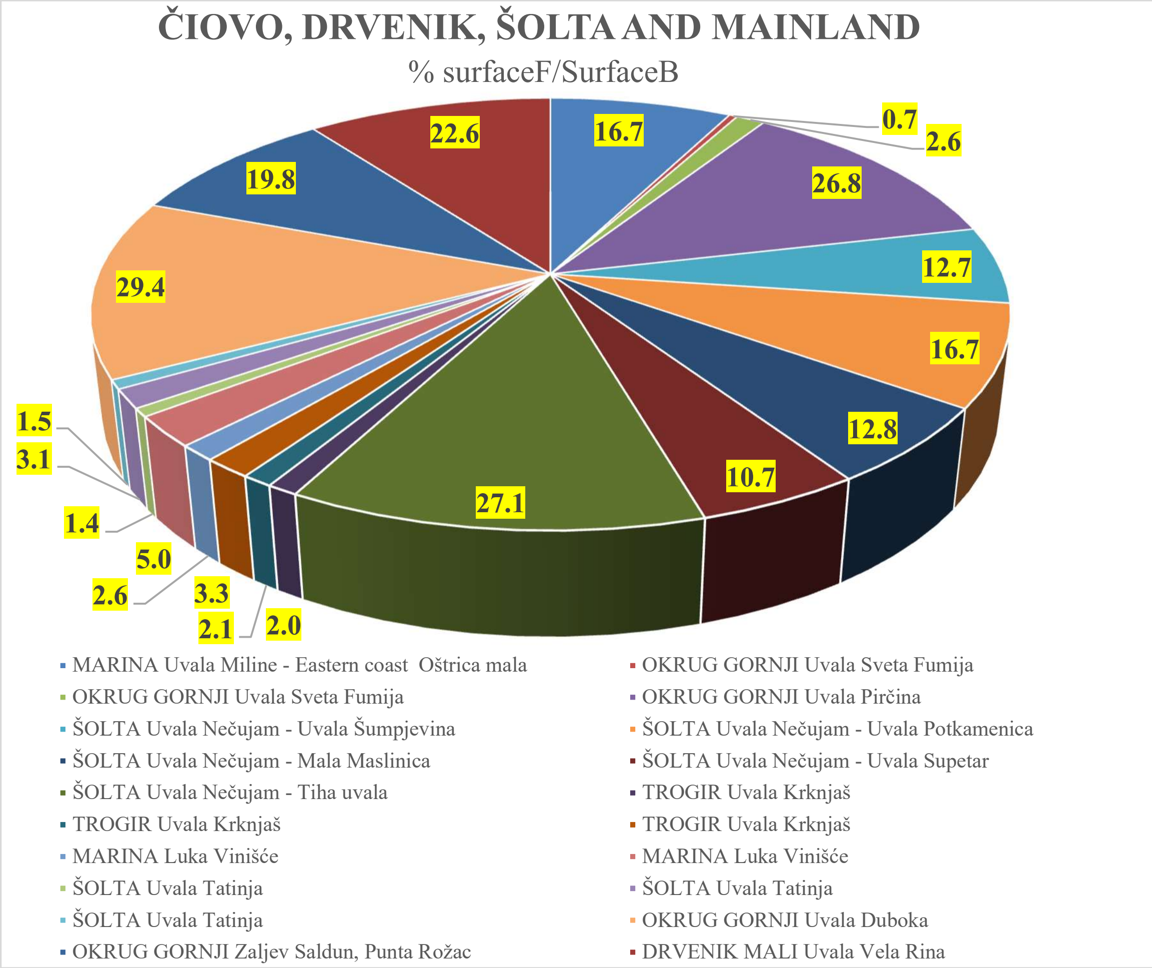


Chart 7. Graphic representation of the share of the field surface in relation to the surface of the bay on the Čiovo, Drvenik, Šolta islands and mainland in percentages

Table 19. Information on the locations of nautical anchorages on Hvar Island

No	Name	Island	Field	surfaceF	surfaceB	percentage	protection	distance	numberF
1	HVAR Luka Soline - Uvala Prevojice	HVAR	A	12,189.12	158,135.45	7.7	partially protected	18.1	2
2	HVAR Luka Soline - Uvala Prevojice	HVAR	B	29,040.95	158,135.45	18.4	partially protected	9.8	2
3	HVAR Luka Soline - west	HVAR	A	18,809.22	55,958.72	33.6	partially protected	10.5	1
4	HVAR Stipanska uvala	HVAR	A	28,014.56	129,531.52	21.6	partially protected	11.9	2
5	HVAR Stipanska uvala	HVAR	B	5,653.71	129,531.52	4.4	partially protected	4.7	2
6	HVAR Uvala Taršće	HVAR	A	19,045.87	270,860.78	7.0	protected	7	2
7	HVAR Uvala Taršće	HVAR	B	39,759.11	270,860.78	14.7	protected	5.2	2
8	HVAR Uvala Vinogradišće	HVAR	A	33,300.56	172,777.22	19.3	protected	15.6	2
9	HVAR Uvala Vinogradišće	HVAR	B	20,184.50	172,777.22	11.7	protected	6.2	2
10	HVAR Ždrilica	HVAR	A	15,461.52	232,623.14	6.6	protected	27.1	4
11	HVAR Ždrilica	HVAR	B	19,223.69	232,623.14	8.3	protected	29.2	4
12	HVAR Ždrilica	HVAR	C	11,217.76	232,623.14	4.8	protected	7.4	4
13	HVAR Ždrilica	HVAR	D	4,294.60	232,623.14	1.8	protected	8.2	4
14	HVAR Uvala Mala Milna	HVAR	A	9,019.93	42,964.85	21.0	unprotected	38.7	1
15	HVAR Vela Garška uvala	HVAR	A	4,173.73	89,446.05	4.7	partially protected	11.9	3
16	HVAR Vela Garška uvala	HVAR	B	2,048.41	89,446.05	2.3	partially protected	18.7	3
17	HVAR Vela Garška uvala	HVAR	C	5,841.32	89,446.05	6.5	partially protected	10.2	3
18	JELSA Luka Lovišće	HVAR	A	8,387.75	143,621.11	5.8	partially protected	5.7	4
19	JELSA Luka Lovišće	HVAR	B	5,235.86	143,621.11	3.6	partially protected	8.6	4
20	JELSA Luka Lovišće	HVAR	C	3,112.82	143,621.11	2.2	partially protected	6.2	4
21	JELSA Luka Lovišće	HVAR	D	7,322.86	143,621.11	5.1	partially protected	6.4	4
22	JELSA Uvala Moster	HVAR	A	4,663.32	63,348.89	7.4	partially protected	5.9	2
23	JELSA Uvala Moster	HVAR	B	5,908.71	63,348.89	9.3	partially protected	3.1	2
24	Uvala Tiha - Malo Stupišće	HVAR	A	1,585.75	17,635.17	9.0	unprotected	19.2	1
25	Uvala Tiha - Veliko Stupišće	HVAR	A	1,649.94	24,401.10	6.8	unprotected	21.6	2
26	Uvala Tiha - Veliko Stupišće	HVAR	B	2,601.84	24,401.10	10.7	unprotected	9.1	2
27	Uvala Tiha - Vucja	HVAR	A	2,793.77	32,982.85	8.5	partially protected	21.8	1
28	Uvala Tiha - Mitki bok	HVAR	A	2,998.57	68,871.31	4.4	partially protected	31	2
29	Uvala Tiha - Mitki bok	HVAR	B	3,301.45	68,871.31	4.8	partially protected	42.7	2
30	Uvala Tiha - Veli Dolac	HVAR	A	9,075.05	43,204.52	21.0	partially protected	9.7	2
31	Uvala Tiha - Veli Dolac	HVAR	B	2,204.46	43,204.52	5.1	partially protected	15.6	2
32	Uvala Tiha - Paklena	HVAR	A	2,911.78	26,374.64	11.0	partially protected	10.5	1
33	JELSA Soline Vrboska	HVAR	A	21,759.24	215,264.65	10.1	unprotected	13.5	1
34	JELSA Uvala Pokrvenik	HVAR	A	6,947.12	96,286.36	7.2	protected	9.6	2
35	JELSA Uvala Pokrvenik	HVAR	B	900.00	96,286.36	0.9	protected	8.1	2
36	STARI GRAD Uvala Hobonj	HVAR	A	3,540.92	19,984.43	17.7	partially protected	4.4	1
37	STARI GRAD Zavala	HVAR	A	3,950.60	89,259.53	4.4	protected	7.8	1
38	SUĆURAJ Luka Mrtinovik	HVAR	A	3,698.50	130,729.53	2.8	partially protected	10.5	1
39	HVAR Uvala Vlaka, Pakleni otoci	HVAR	A	17,977.06	192,140.53	9.4	unprotected	24.5	1
40	HVAR Uvala V. Zaraće	HVAR	A	16,066.28	75,178.13	21.4	partially protected	23.2	1
41	HVAR Uvala Pribinja	HVAR	A	22,435.02	124,493.66	18.0	protected	50.9	1
		Sum		**438,307.23**	**4,851,116.14**	**401.0**		**610.0**	**89**
		Mean		**10,690.42**	**118,319.91**	**9.8**	**12 protected**	**14.9**	**2.2**
		Min		**900.00**	**17,635.17**	**0.9**	**23 partially protected**	**3.1**	**1**
		Max		**39,759.11**	**270,860.78**	**33.6**	**6 unprotected**	**50.9**	**4**

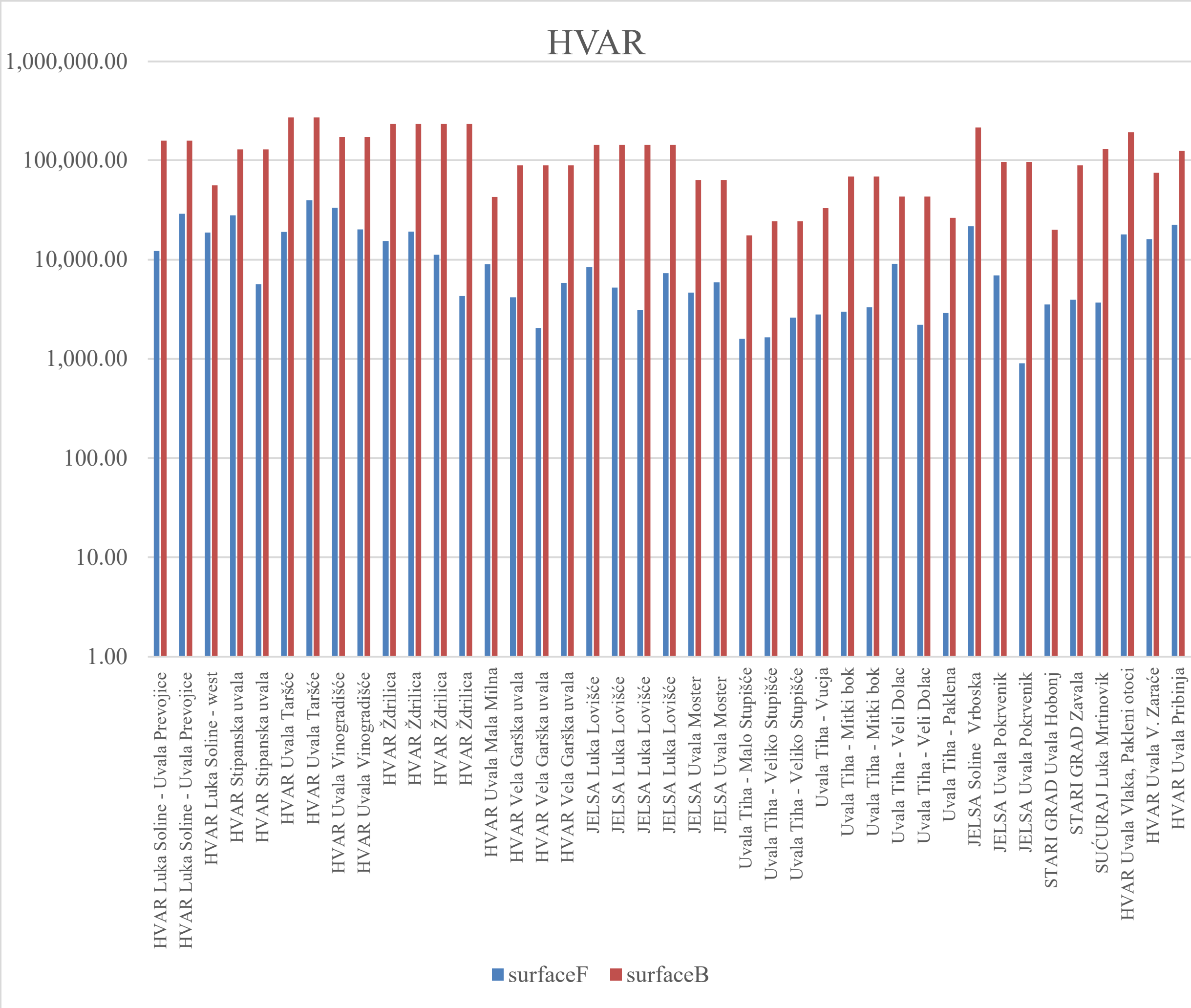


Chart 8. Graphic representation of the share of the field surface in relation to the surface of the bays on Hvar Island in the logarithmic scale

Chart 8 graphically represents the ratio of the field surface in relation to the surface of bays, while Chart 9. graphically shows the share of field surface in relation to the surface of the bays on the Island of Hvar in percentage.

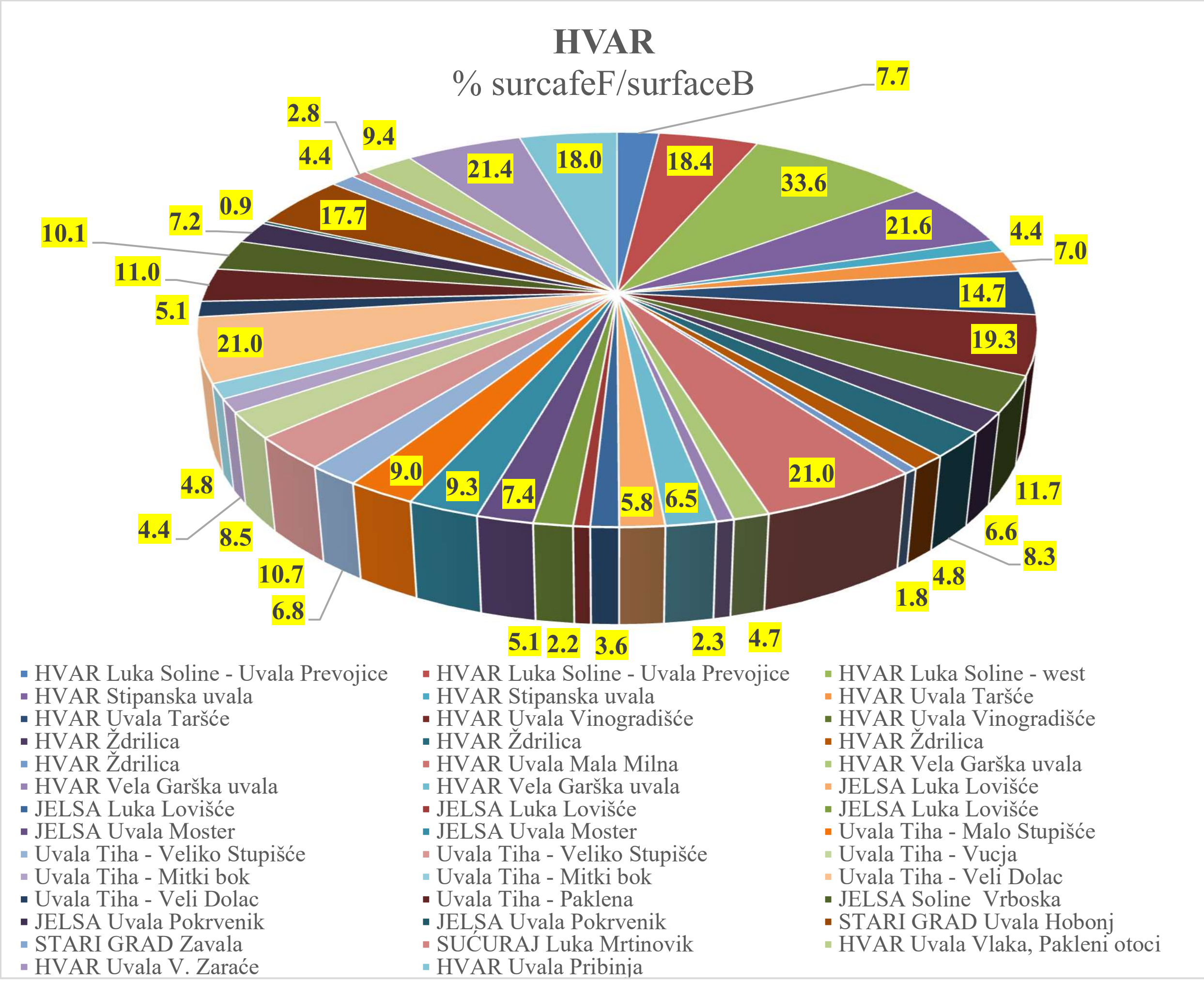


Chart 9. Graphic representation of the share of the field surface in relation to the surface of the bays on Hvar Island in percentages

Table 20 presents individual data for the locations of nautical anchorages on Vis Island.

Table 20. Data on the locations of nautical anchorages on Vis Island

No	Name	Island	Field	surfaceF	surfaceB	percentage	protection	distance	numberF
1	KOMIŽA Uvala Mezuporat	VIS	A	5,929.95	79,469.29	7.5	unprotected	27.2	1
2	VIS Budikovac	VIS	A	19,034.87	48,094.56	39.6	unprotected	8.7	1
3	VIS Uvala Stončica	VIS	A	22,354.01	190,158.53	11.8	protected	8.1	1
4	VIS Uvala Stončica - Uvala Vela Čavojnica	VIS	A	13,268.09	77,017.13	17.2	protected	12.3	1
5	KOMIŽA Biševska luka	VIS	A	9,156.65	98,277.88	9.3	protected	20	1
6	VIS Rukavac	VIS	A	8,473.78	140,579.16	6.0	partially protected	21.9	2
7	VIS Rukavac	VIS	B	4,936.84	140,579.16	3.5	partially protected	3.1	2
8	VIS Srebrna	VIS	A	10,809.48	50,893.55	21.2	partially protected	14	1
9	VIS Uvala Stiniva	VIS	A	7,897.21	95,881.30	8.2	partially protected	1.9	1
10	VIS Uvala Ruda	VIS	A	4,375.82	91,277.43	4.8	protected	12.3	2
11	VIS Uvala Ruda	VIS	B	6,871.98	91,277.43	7.5	protected	11	2
			Sum	**113,108.68**	**1,103,505.42**	**136.7**		**140.5**	**15**
			Mean	**10,282.61**	**100,318.67**	**12.4**	**5 protected**	**12.8**	**1.4**
			Min	**4,375.82**	**48,094.56**	**3.51**	**4 partially protected**	**1.9**	**1**
			Max	**22,354.01**	**190,158.53**	**39.58**	**2 unprotected**	**27.2**	**2**

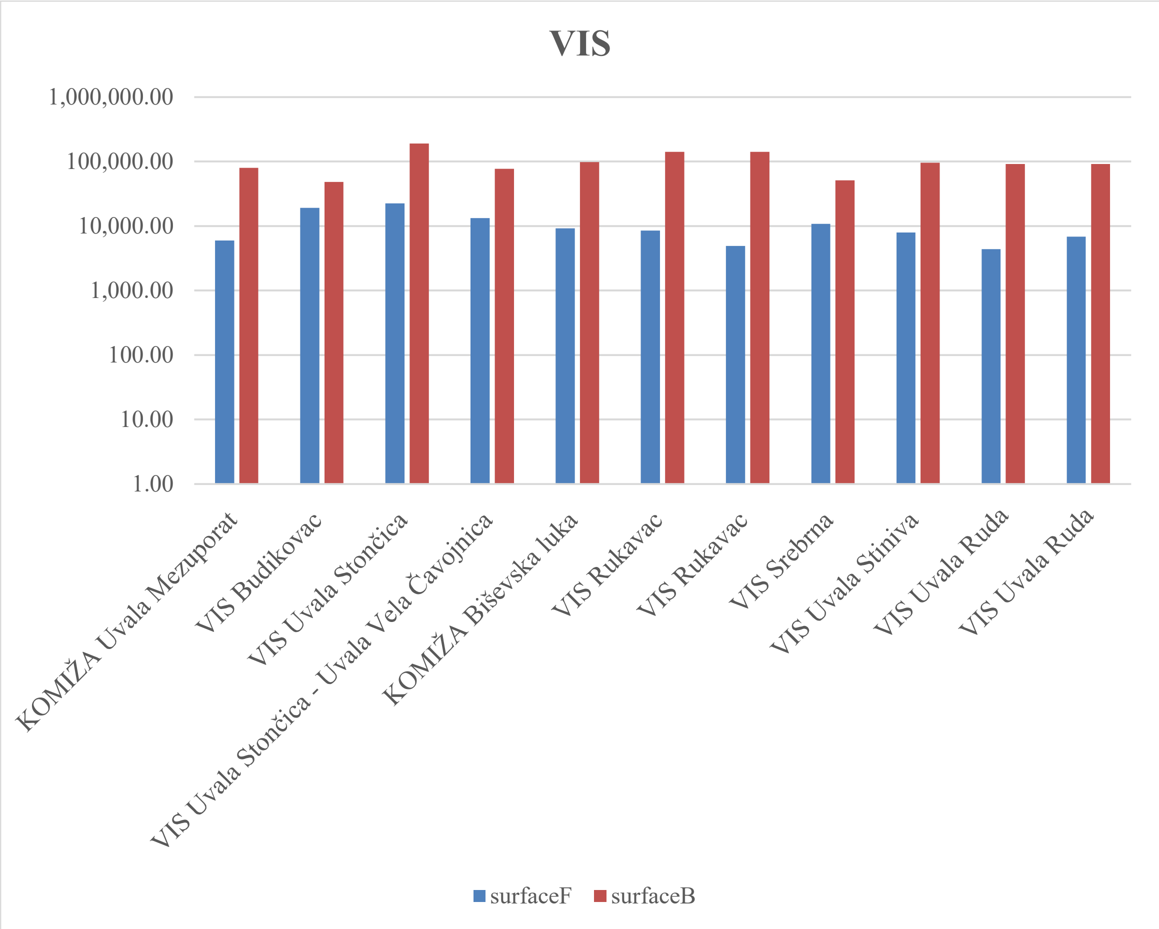


Chart 10. Graphic representation of the share of the field surface in relation to the surface of the bays on Vis Island on the logarithmic scale

Chart 10 graphically represents the ratio of the field surface in relation to the surface of bays, while Chart 11 graphically shows the share of field surface in relation to the surface of the bays on Vis Island in percentage.

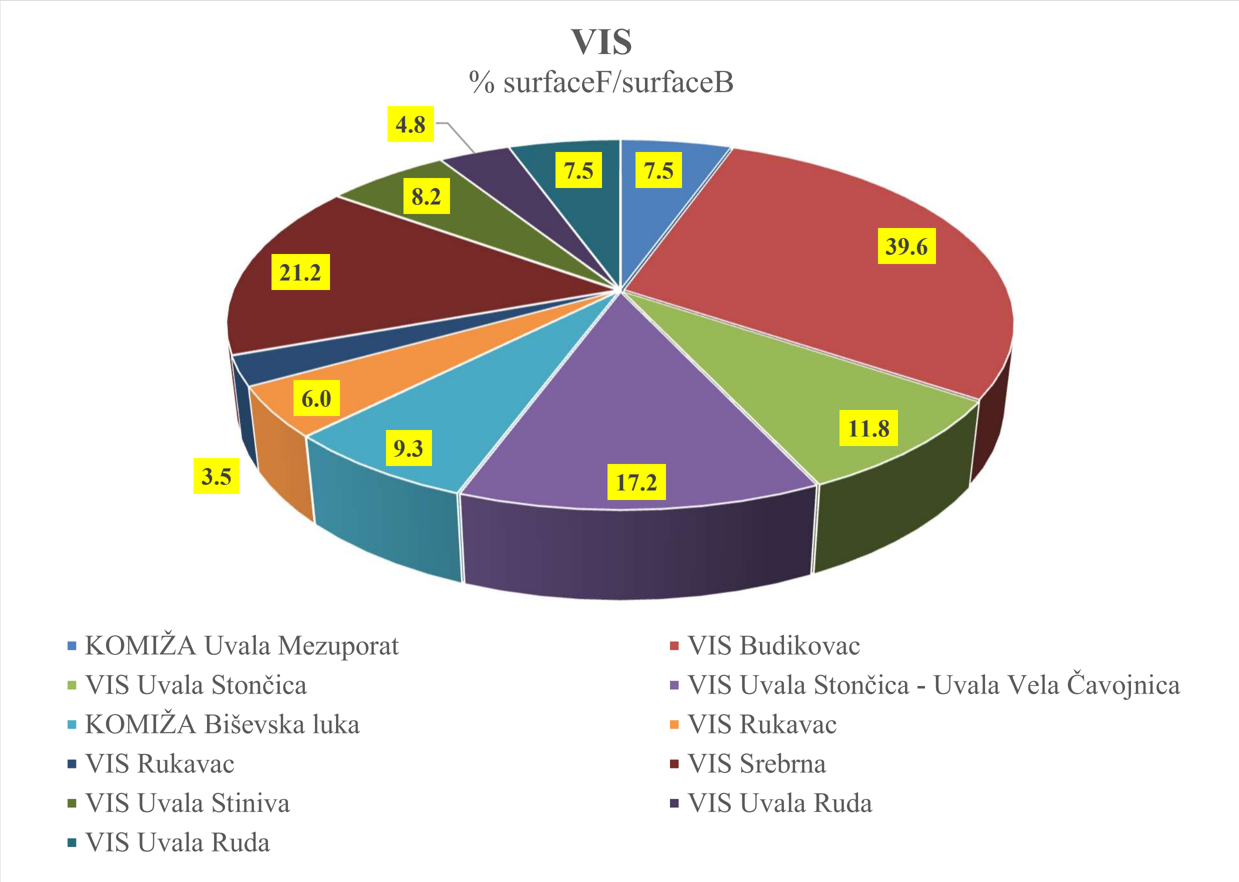


Chart 11. Graphic representation of the share of the field surface in relation to the surface of the bays on Vis Island in percentages

Table 21 presents summary data of field surfaces grouped by geographical areas, i.e. by islands, for all analysed locations of nautical anchorages in Split-Dalmatia County.

Table 21. Summary data on the areas of the nautical anchorages in the area of SDC

Location	partially protected	protected	unprotected	SUM
BRAČ	47,908.61	28,029.56	35,700.46	111,638.63
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	102,903.37	124,064.24	95,562.88	322,530.49
HVAR	186,993.12	196,720.35	54,593.76	438,307.23
VIS	32,117.31	56,026.55	24,964.82	113,108.68
SUM	**369,922.41**	**404,840.70**	**210,821.92**	**985,585.03**

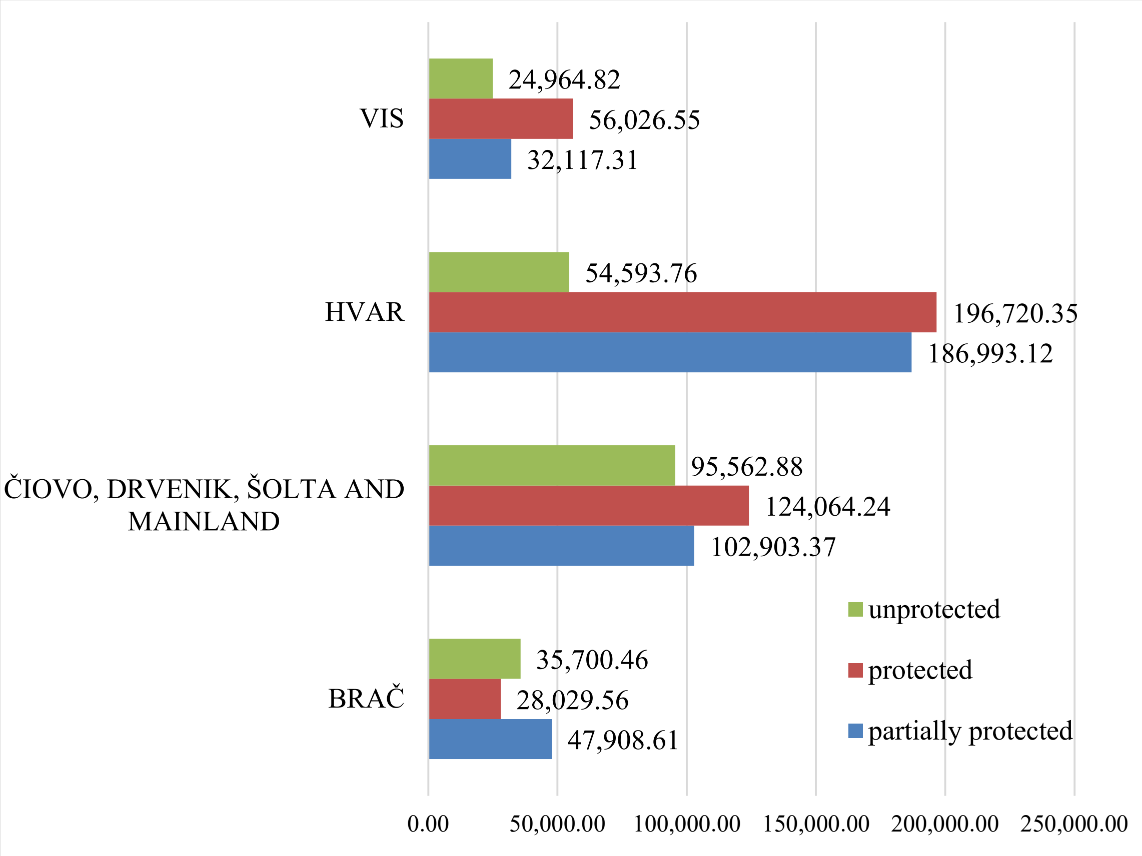


Chart 12. The total surface of anchor fields by location in SDC

Table 22. Aggregate data on the surface of bays and the locations of nautical anchorages in the area of SDC

Location	partially protected	protected	unprotected	SUM
BRAČ	2,606,298.65	338,741.81	258,788.12	3,203,828.58
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	2,548,048.53	2,485,011.27	403,891.73	5,436,951.53
HVAR	2,110,214.25	2,224,094.48	516,807.41	4,851,116.14
VIS	427,933.17	548,008.40	127,563.85	1,103,505.42
SUM	**7,692,494.60**	**5,595,855.96**	**1,307,051.11**	**14,595,401.67**

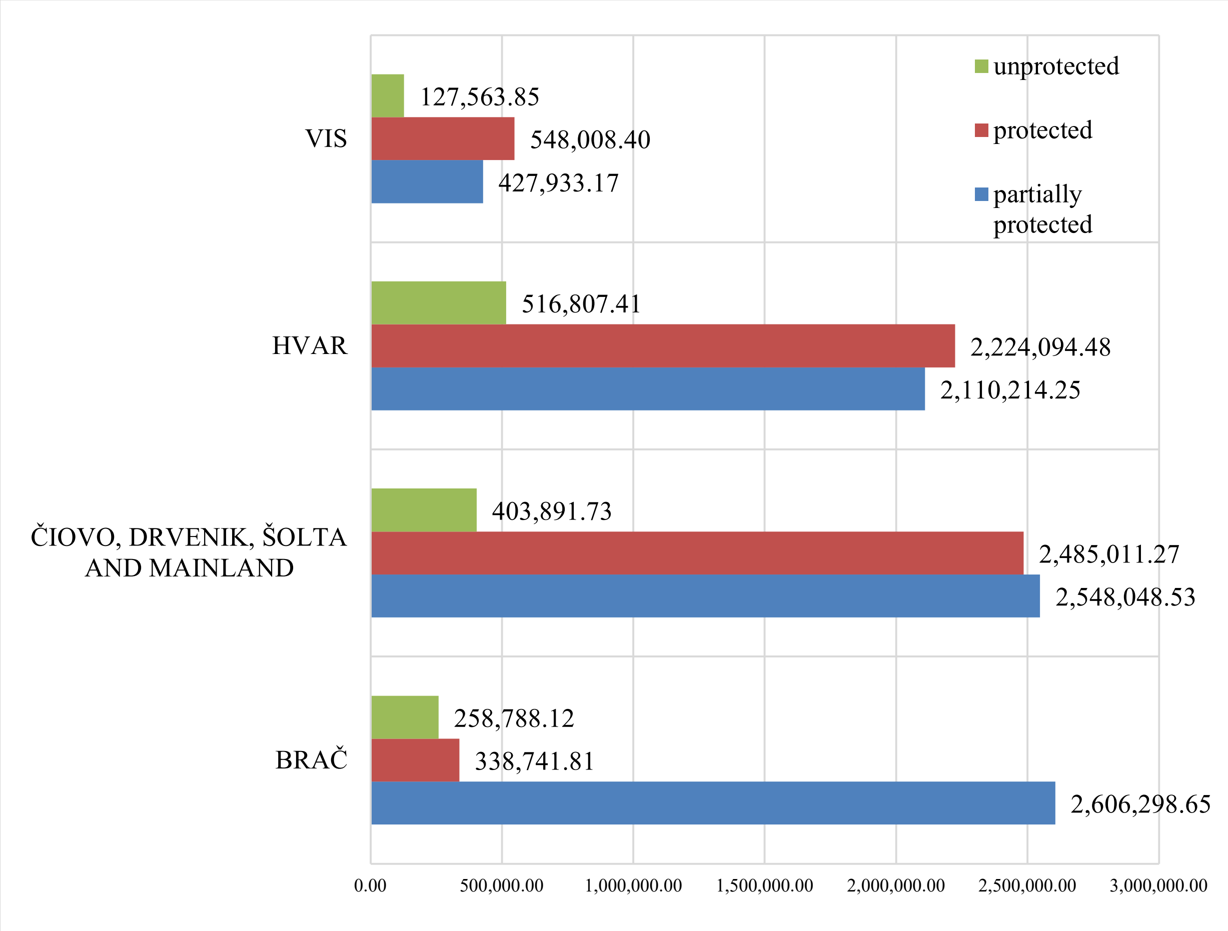


Chart 13. The total areas of bays at the future locations of nautical anchorages in SDC

Chart 13 graphically summarises the surfaces of bays at the future locations of nautical anchorages, grouped by islands.

Table 23 presents the mean values of the shares of field surface in the surface of bays of locations in SDC grouped by geographical locations, i.e. islands.

Table 23. Aggregate data on the mean share of the field surface in the surface of the bay of nautical anchorages in the area of SDC

Location	partially protected	protected	unprotected	MEAN
BRAČ	4.25	10.68	16.29	9.06
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	10.75	5.54	25.97	10.97
HVAR	9.97	8.74	11.15	9.78
VIS	9.75	10.12	23.52	12.43
MEAN	**9.32**	**8.61**	**16.50**	**10.28**

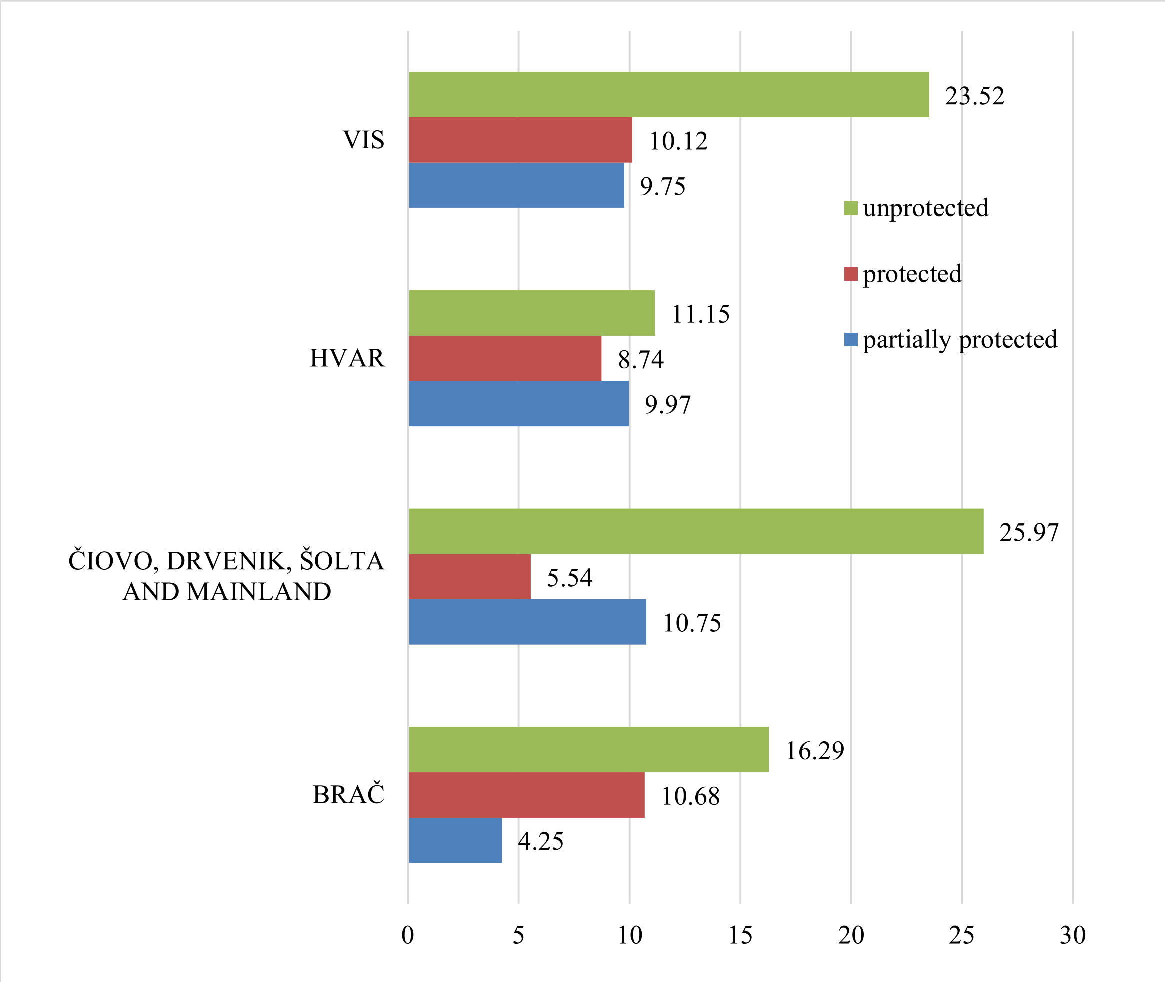


Chart 14. Presentation of the mean percentage share of the field surface in the surface of the bays in the locations of SDC, grouped by islands.

Chart 14 graphically shows the mean shares of field surface in bay surfaces grouped by islands in percentages. Table 24. presents the total number of unprotected, partially protected, and protected bays grouped by geographical areas, islands in Split-Dalmatia County.

Table 24. Aggregate data on the number of unprotected, partially protected, and protected bays, locations of nautical anchorages in the area of SDC.

Location	partially protected	protected	unprotected	COUNT
BRAČ	7	3	4	14
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	13	5	2	20
HVAR	23	12	6	41
VIS	4	5	2	11
COUNT	**47**	**25**	**14**	**86**

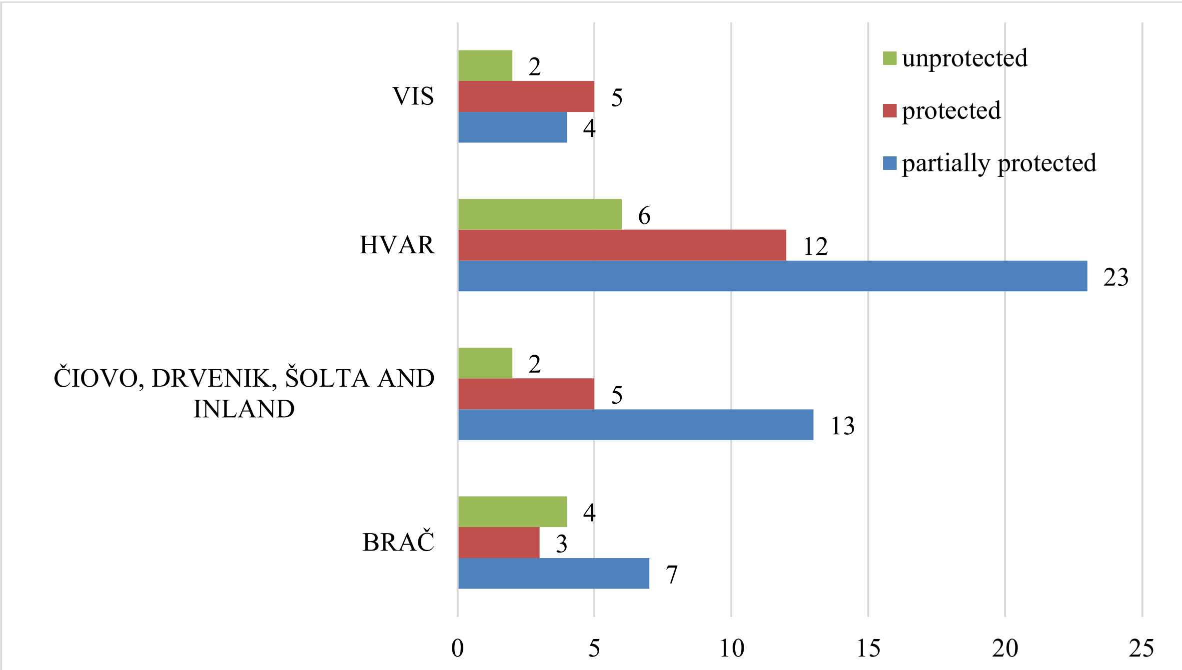


Chart 15. The total number of unprotected, partially protected, and protected bays at SDC locations.

Table 25 presents summary data of the locations of nautical anchorages based on the mean distances of the fields from the coast grouped by geographical areas, islands in the area of the SDC.

Table 25 Aggregate data on the mean distances of the fields from the coast of the locations of nautical anchorages in the area of SDC.

Location	partially protected	Protected	unprotected	MEAN
BRAČ	12.27	7.37	11.53	11.01
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	24.47	43.44	62.45	33.01
HVAR	13.09	15.19	21.10	14.88
VIS	10.23	12.74	17.95	12.77
MEAN	**15.87**	**19.41**	**23.82**	**18.20**

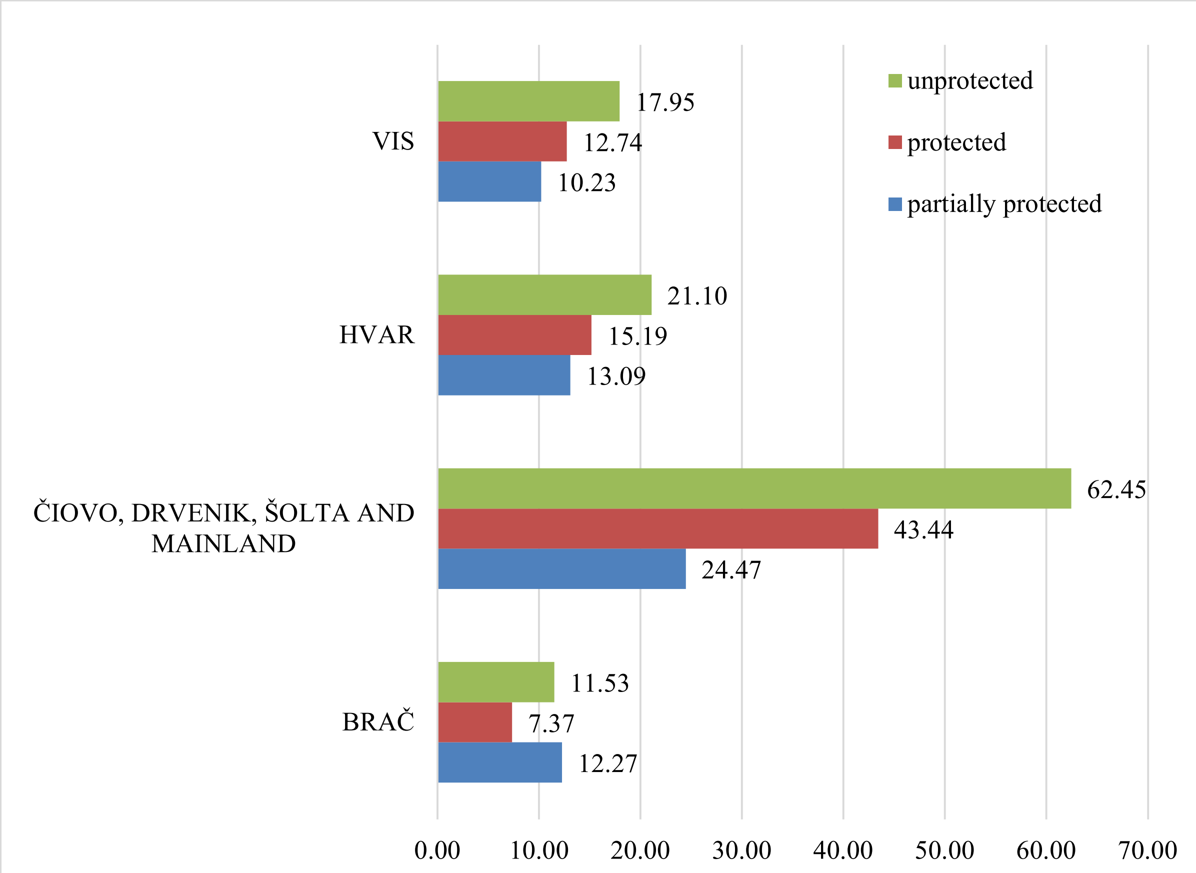


Chart 16. The mean (average) distances of the fields from the shore at the future locations of nautical anchorages in the SDC

Table 26. Summary data on the mean number of fields on the bays of nautical anchorage locations in SDC

Location	partially protected	Protected	unprotected	MEAN
BRAČ	2.14	1.67	1.50	1.86
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1.92	1.80	1.00	1.80
HVAR	2.22	2.50	1.33	2.17
VIS	1.50	1.40	1.00	1.36
MEAN	**2.06**	**2.04**	**1.29**	**1.93**

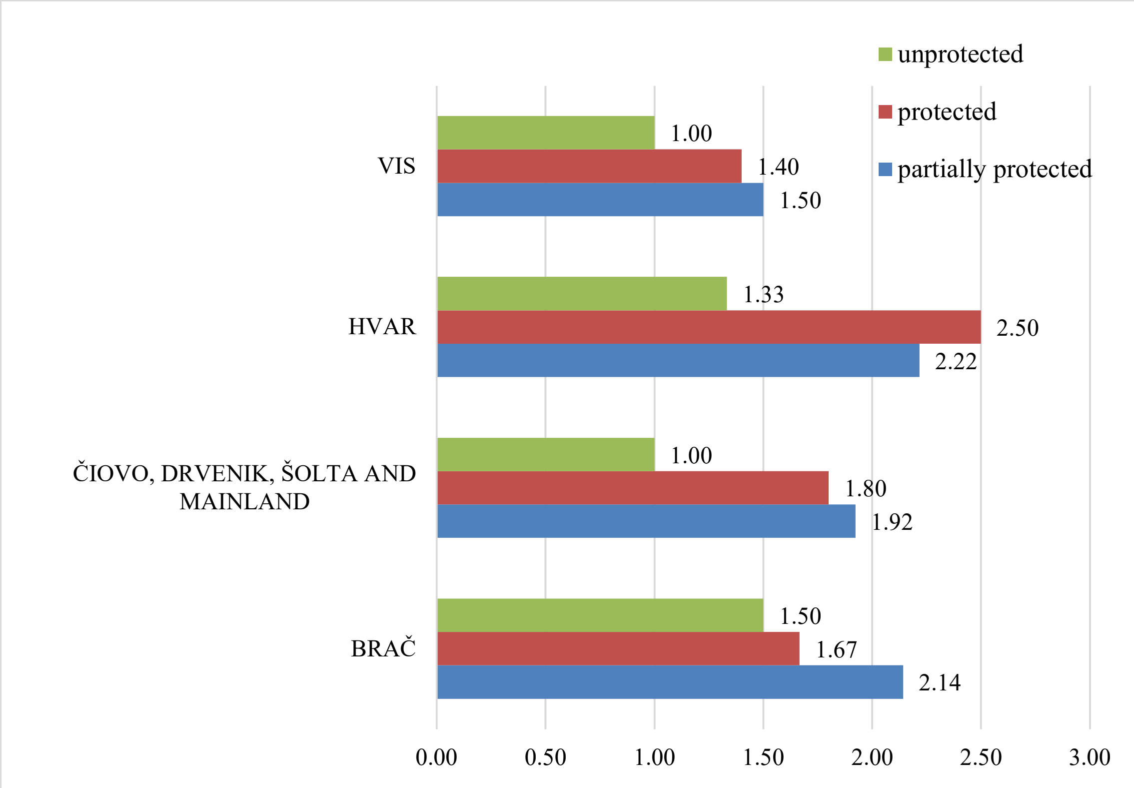


Chart 17. The mean number of fields in the bays of the nautical anchorages of SDC

As previously pointed out, the input data was obtained based on several years of research using GIS and based on detailed knowledge of all the existing and future planned locations of nautical anchorages in the area of Split-Dalmatia County.

Table 27 shows the summary data for all 86 analysed locations.

Table 27. Summary data for all locations

Island and mainland	SUM/MEAN/TOTAL	surfaceF	surfaceB	percentage	protection	distance	numberF
BRAČ	SUM	111,638.63	3,203,828.58	126.91	**4**	154.10	26
	MEAN	16,126.52	228,844.90	9.06	**7**	11.01	1.86
	TOTAL	**14**	**14**	**14**	**3**	**14**	**14**
ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	SUM	322,530.49	5,436,951.53	219.44	**2**	660.20	36
	MEAN	16,126.52	271,847.58	10.97	**13**	33.01	1.80
	TOTAL	**20**	**20**	**20**	**5**	**20**	**20**
HVAR	SUM	438,307.23	4,851,116.14	401.01	**6**	610.00	89
	MEAN	10,690.42	118,319.91	9.78	**23**	14.88	2.17
	TOTAL	**41**	**41**	**41**	**12**	**41**	**41**
VIS	SUM	113,108.68	1,103,505.42	136.68	**2**	140.50	15
	MEAN	10,282.61	100,318.67	12.43	**4**	12.77	1.36
	TOTAL	**11**	**11**	**11**	**5**	**11**	**11**
	SUM	985,585.03	14,595,401.67	884.03	**14**	1,564.80	166
	MEAN	11,460.29	169,713.97	10.28	**47**	18.20	1.93
	TOTAL	**86**	**86**	**86**	**25**	**86**	**86**
	MIN	900.00	11,800.58	0.28		0.00	1
	MAX	76,654.37	723,767.14	39.58		81.20	4

Data - Traffic at the locations of nautical anchorages

Chart 18 represents the sums of field surface group by islands/mainland; Chart 19 represents the mean of field surface group by islands/mainland; Chart 20 represents the sums of bay surface group by islands/mainland, while Chart 21 represents the mean of bays surface group by islands/mainland.

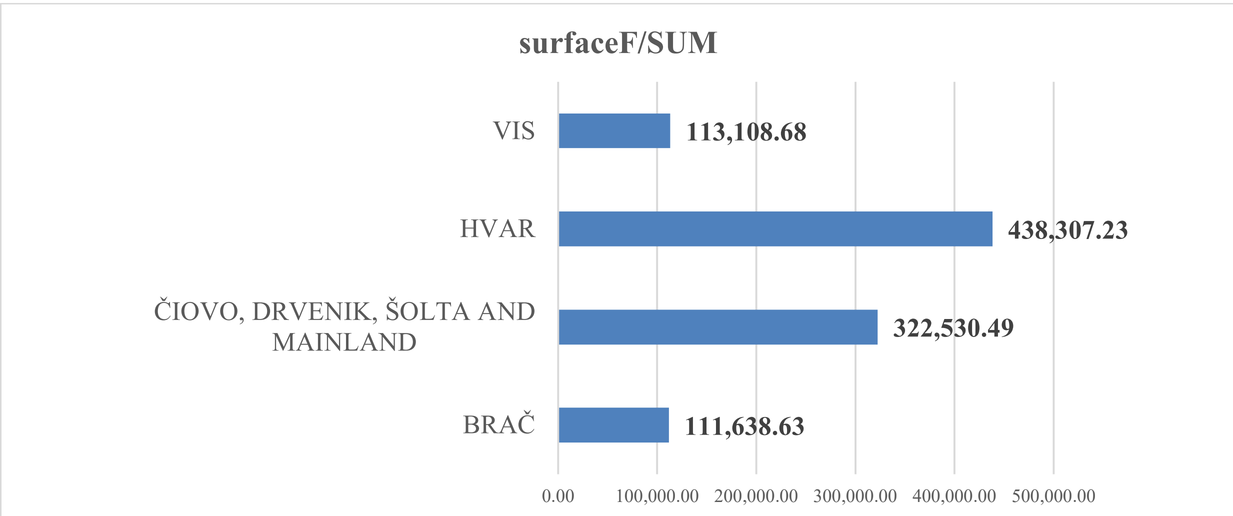


Chart 18. Sums of field surface group by islands/mainland

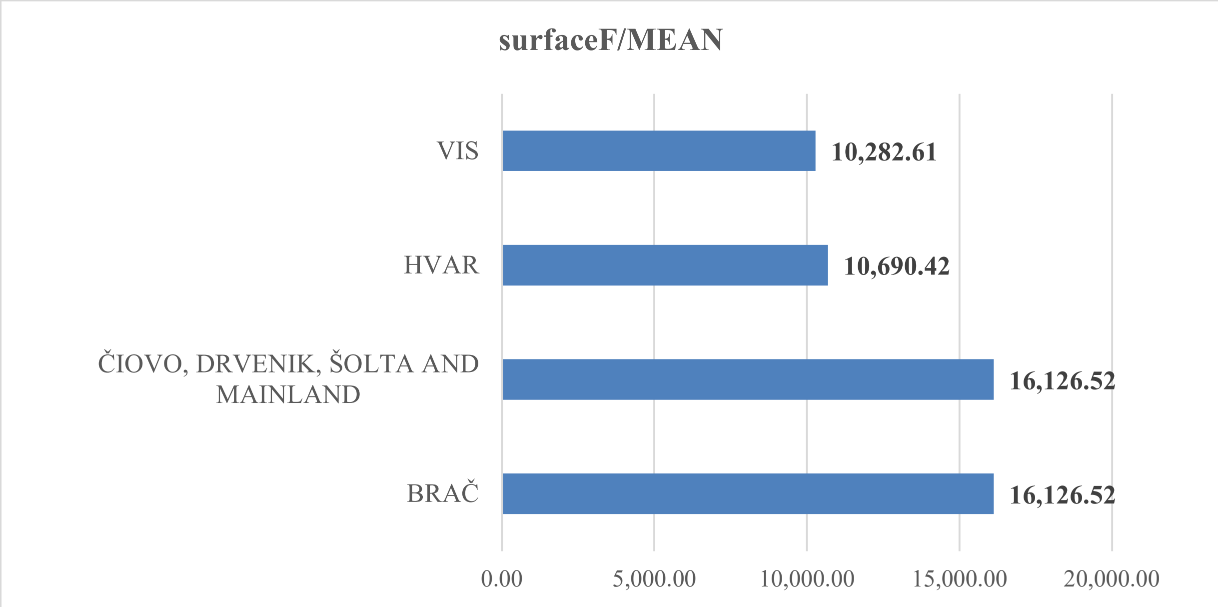


Chart 19. Means of field surface group by islands/mainland

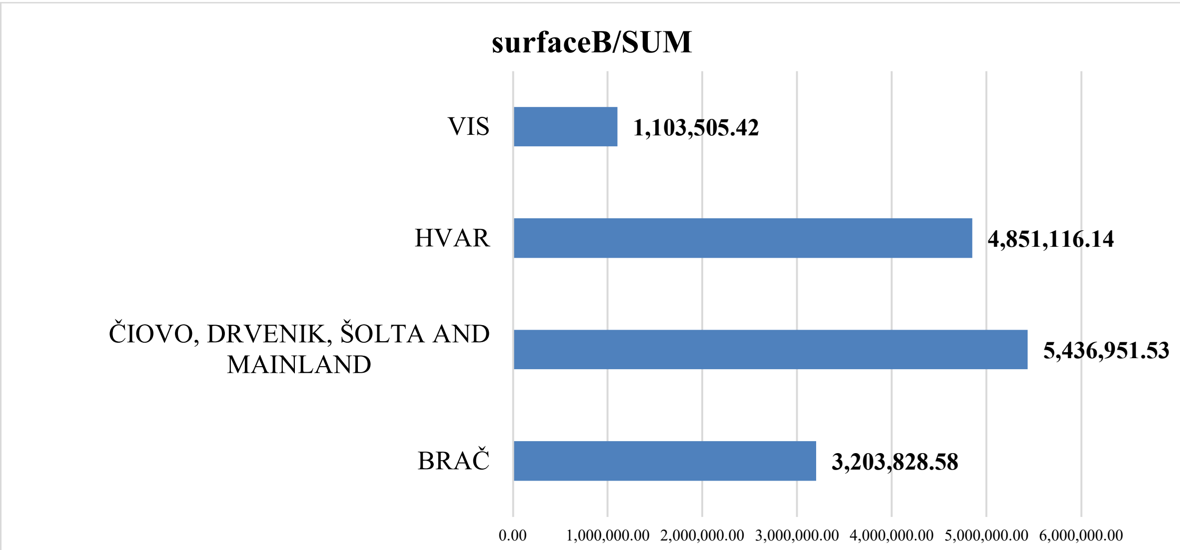


Chart 20. Sums of bay surface by islands/mainland

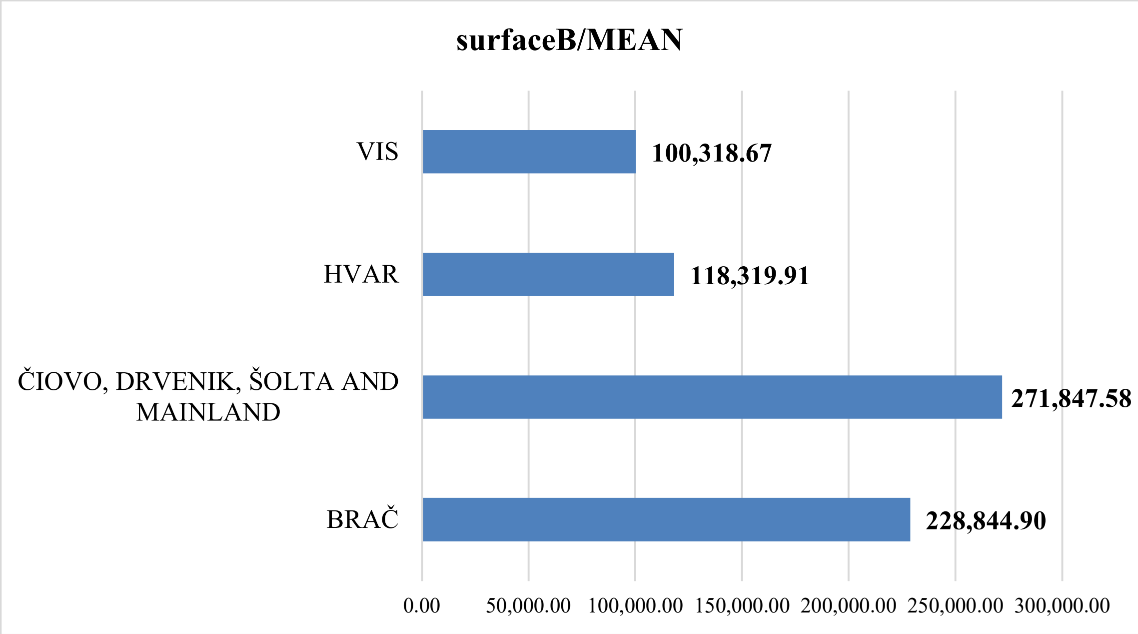


Chart 21. Means of bay surface by islands/mainland

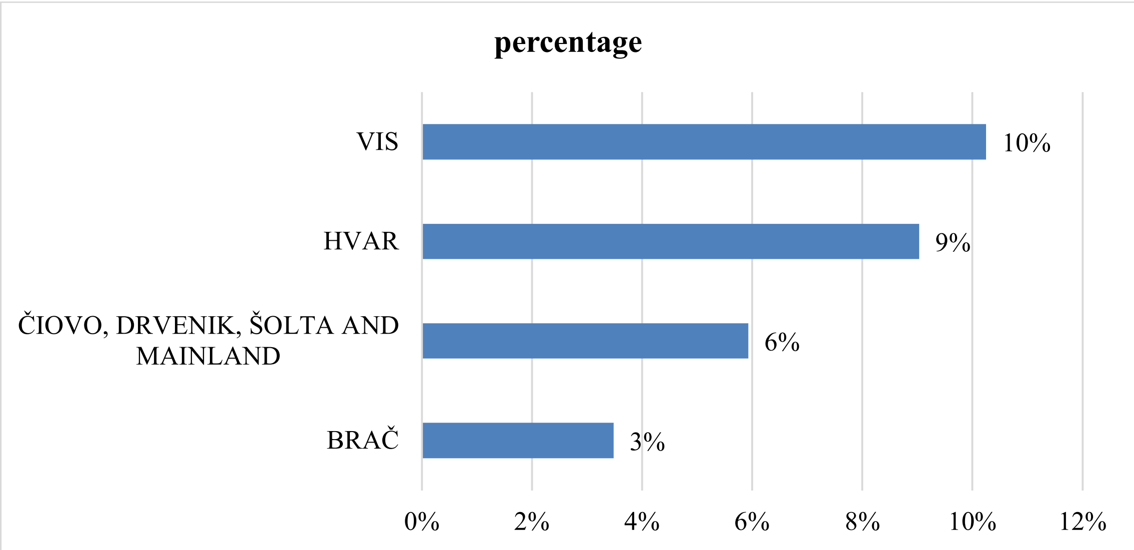


Chart 22. The percentage share of the field surface in the surface of the bay grouped by islands/mainland

Chart 22 represents the percentage share of the field surface in the surface of the bay grouped by islands/mainland, while Chart 23 represents the mean distance from the coast grouped by island/mainland.

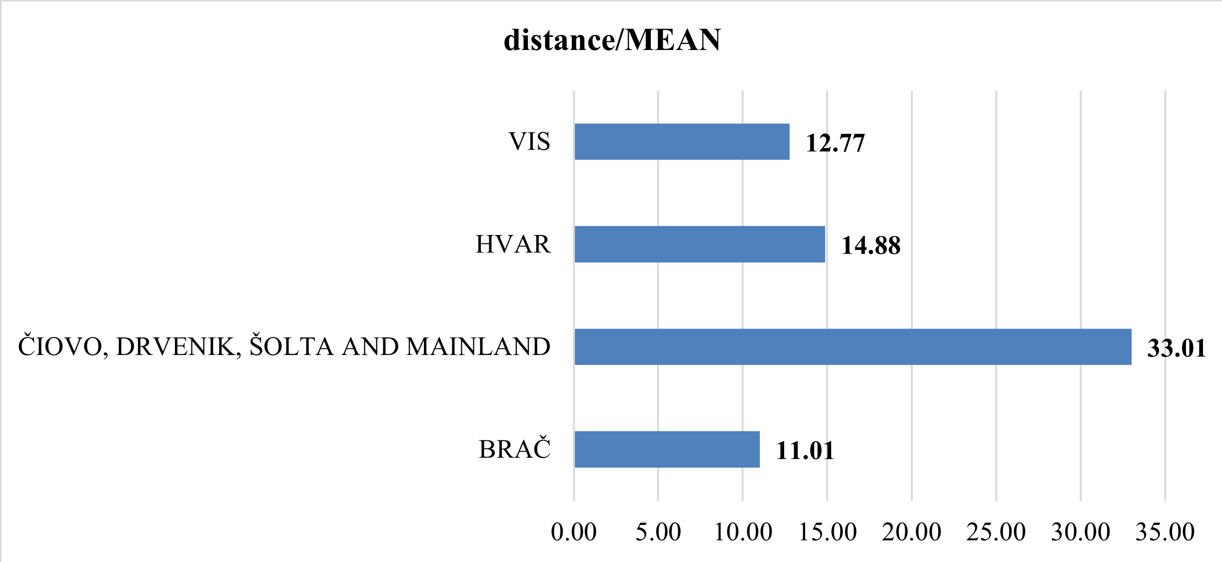


Chart 23. Mean distance from the coast grouped by island/mainland

Table 28 shows that only 4 (four) out of 86 locations of nautical anchorages are located near traffic routes up to 500 meters, so they are assigned a value of 5 (five) for this criterion. All other locations have a value of 1 (one) for this factor.

Table 28. Data on anchoring locations that are near maritime routes

No	NAME	ISLAND	SEA TRAFFIC
44	HVAR Ždrilica	HVAR	5
45	HVAR Ždrilica	HVAR	5
46	HVAR Ždrilica	HVAR	5
47	HVAR Ždrilica	HVAR	5

Data - Official anchorages at nautical anchorage locations

Each of the 86 nautical anchorage locations is eligible and is not in the official anchorage area, so they are all assigned the value of 1 (one) for this factor.

Data - Underwater cables and pipelines at the locations of nautical anchorages

Except for Uvala Mala on Hvar Island, all other (85) nautical anchorage locations are eligible as anchoring sites. Table 29 shows that only one out of the 86 nautical anchorage locations is close to underwater cables and pipelines at a distance of up to 500 meters, so this location is assigned the value of 5 (five). All other locations meet this condition and are located further than 500 meters from underwater cables and pipelines, so they were assigned the value of 1 (one).

Table 29. Data on locations near to cables and pipelines

No	NAME	ISLAND	UNDERWATER CABLES AND PIPELINES
48	HVAR Uvala Mala Milna	HVAR	5

Data - Collision hazards at nautical anchorage locations

Table 30 shows that only five (5) out of 86 locations of nautical anchorages have a high risk (assigned value 4) or a very high (assigned value 5) risk of collision. Other locations have a medium risk of collision, so they are assigned the value of 3.

Table 30. Data on locations with a high or extremely high risk of collision

No	NAME	ISLAND	HIGH OR VERY HIGH RISK OF COLLISION
44	HVAR Ždrilica	HVAR	5
45	HVAR Ždrilica	HVAR	5
46	HVAR Ždrilica	HVAR	5
47	HVAR Ždrilica	HVAR	5
76	KOMIŽA Uvala Mezuporat	VIS	4

Data - Depth at the locations of nautical anchorages

All 86 locations meet the condition of sufficient depth, so they are all assigned the value of 1 (one).

Data - Tides and sea currents at the locations of nautical anchorages

Table 31 shows that only four (4) out of 86 nautical anchorage locations are exposed to high tides and sea currents, so they were assigned the value of five (5) for this field. All other locations were assigned the value of one (1) for this factor.

Table 31. Data on locations with high/very high tides and sea currents

No	NAME	ISLAND	TIDES AND SEA CURRENTS
44	HVAR Ždrilica	HVAR	5
45	HVAR Ždrilica	HVAR	5
46	HVAR Ždrilica	HVAR	5
47	HVAR Ždrilica	HVAR	5
76	KOMIŽA Uvala Mezuporat	VIS	4

Data - Proximity to public ports at the locations of nautical anchorages

All locations of nautical anchorages meet the condition of proximity to public ports because they are located far from public ports, so according to this factor they were all assigned the value of 1 (one).

Data - Vicinity to public moorings at nautical anchorage locations

Table 32. Data on locations that are near the existing moorings

No	NAME	ISLAND	VICINITY TO EXISTING MOORINGS
76	KOMIŽA Uvala Mezuporat	VIS	5

Table 32 shows that only one location of nautical anchorages is near the existing moorings, so the value of 5 (five) was assigned to it for this factor. For all other locations, the value of this factor is 1 (one).

Data - Environmental elements at the locations of nautical anchorages

Table 33. Display of data on locations close to the existing anchorages

No	NAME	ISLAND OR MAINLAND	ELEMENTS OF THE ENVIRONMENT (Ecological Network NATURA 2000)
9	PUČIŠĆA Luka Pučišće	BRAČ	1
10	PUČIŠĆA Luka Pučišće	BRAČ	1
11	POSTIRA Uvala Lovrečina	BRAČ	1
13	SUTIVAN Uvala Vića	BRAČ	1
14	SUTIVAN Uvala Stipanska	BRAČ	1
15	MARINA Uvala Miline - Eastern coast Oštrica mala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
19	ŠOLTA Uvala Nečujam - Uvala Šumpjevina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
20	ŠOLTA Uvala Nečujam - Uvala Potkamenica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
21	ŠOLTA Uvala Nečujam - Mala Maslinica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
22	ŠOLTA Uvala Nečujam - Uvala Supetar	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1

23	ŠOLTA Uvala Nečujam - Tiha uvala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
27	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
28	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
32	OKRUG GORNJI Uvala Duboka	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
33	OKRUG GORNJI Zaljev Saldun, Punta Rožac	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
34	DRVENIK MALI Uvala Vela Rina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
48	HVAR Uvala Mala Milna	HVAR	1
75	HVAR Uvala Pribinja	HVAR	1

Table 33 shows that only 18 out of 86 locations of nautical anchorages are not located near the areas in the Natura Ecological Network, so they were assigned the value of one (1). All other locations are in an area within the Natura Ecological Network and were assigned the value of five (5).

This is done in order to analyse the value of this criterion as well - the factors that meet or do not meet these criteria must be assigned a numerical value in a certain range. According to this and subsequent criteria, whole numbers from one (1) to five (5) were taken. For example, if the location of a nautical anchorage is located in the area of the Natura Ecological Network, it is assigned the maximum value of five (5). Otherwise, according to this factor, the location was assigned the value of one (1). The objective of the criteria for the environment in MCA methods is the minimisation, which essentially means that the goal is to favour those locations that are not included in the Natura ecological network.

Data - Elements of the adverse impact of anchoring on the seabed

Table 34. Data on locations where the harmful impact of anchoring on the seabed is observed

No	NAME	ISLAND OR MAINLAND	HARMFULNESS OF ANCHORING A VESSEL ON THE SEABED
9	PUČIŠĆA Luka Pučišće	BRAČ	1
10	PUČIŠĆA Luka Pučišće	BRAČ	1
11	POSTIRA Uvala Lovrečina	BRAČ	1
13	SUTIVAN Uvala Vića	BRAČ	1
14	SUTIVAN Uvala Stipanska	BRAČ	1

15	MARINA Uvala Miline - Eastern coast Oštrica mala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
19	ŠOLTA Uvala Nečujam - Uvala Šumpjevina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
20	ŠOLTA Uvala Nečujam - Uvala Potkamenica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
21	ŠOLTA Uvala Nečujam - Mala Maslinica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
22	ŠOLTA Uvala Nečujam - Uvala Supetar	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
23	ŠOLTA Uvala Nečujam - Tiha uvala	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
27	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
28	MARINA Luka Vinišće	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
32	OKRUG GORNJI Uvala Duboka	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
33	OKRUG GORNJI Zaljev Saldun, Punta Rožac	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
34	DRVENIK MALI Uvala Vela Rina	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	1
48	HVAR Uvala Mala Milna	HVAR	1
75	HVAR Uvala Pribinja	HVAR	1

Table 34 shows that only 18 out of 86 sites of nautical anchorages do not have a negative impact on the seabed when anchoring vessels, while this impact is extremely damaging in other locations. For this reason, these locations were assigned the value of one (1). All other locations were given the value of five, the maximum value, corresponding to the factor of harmfulness of anchoring a vessel to the seabed.

Data: Archaeological sites at the locations of nautical anchorages

All observed locations of nautical anchorages meet the condition of vicinity to public ports because they are located far from public ports, so they were all assigned a value of one (1) according to this factor.

Table 35 shows that only one of the 86 locations is located in the area of archaeological sites, so this location is assigned the value of five (5) for this factor. For all other locations in the field "Archaeological Sites," the value assigned is one (1).

Table 35. Data on locations near the existing berths

No	NAME	ISLAND OR MAINLAND	ARCHAEOLOGICAL SITES
21	ŠOLTA Uvala Nečujam - Mala Maslinica	ČIOVO, DRVENIK, ŠOLTA AND MAINLAND	5

6.2. Selection and determination of criteria weight values in MCA methods

In addition to the presented input data, this chapter presents all the premises and assumptions, as well as the elements necessary to apply the methods of MCA.

In order to achieve the desired goal, a case study was made using several methods of MCA, namely: AHP, TOPSIS, combined hybrid AHP-TOPSIS-2N and PROMETEE II methods. Given that the assumptions depend on the applied MCDM method, they are shown below in Table 36:[120]

1. Criteria marks (C1 to C17);
2. Names of the criteria used;
3. Unit of measurement;
4. Minimum and maximum values for each criterion.

Table 36. Label, criteria name, measure unit, and range of input data

Label	Criterion name	Measure unit	Range	
			Min	Max
C_1	Field surface (**surfaceF**)	m^2	900	76654.4
C_2	Area of the bay (**surfaceB**)	m^2	11800.6	723767
C_3	The percentage of the field area in the bay area (**percentage**)	%	0.28454	39.578
C_4	Protection of the bay (**protection**)	Whole number: 1 - Protected; 5 - Partially protected; 9 - Non protected	1	9
C_5	Distance from the coast (**distance**);	m	0	81.2
C_6	Number of anchorage fields in the bay (**numberF**)	Whole number	1	4
C_7	Presence of maritime traffic (**traffic**)	Whole number: If the proximity of the main traffic routes is less than 500 m: 1 - No; 5 - Yes	1	5
C_8	Presence of an official anchorage (**anchorage**)	Whole number: If it is in the area of official anchorages: 1 - No; 5 - Yes	1	5
C_9	Presence of underwater cables and pipelines (**cables**)	Whole number: The proximity of cables and pipelines is less than 500 m: 1 - No; 5 - Yes	1	5
C_{10}	Risk of collision (**danger**)	Whole number: 1 - negligible; 2 - small; 3 - mean; 4 - big; 5 - very big	1	5
C_{11}	Depth (**depth**)	Whole number: 1 - Satisfactory; 5 - Unsatisfactory	1	5
C_{12}	Tide level and existence of sea currents (**tide**)	Whole number: 1 - small; 3 - mean; 5 - big	1	5
C_{13}	Proximity to public ports (**proximityP**)	Whole number: 1 - No; 5 - Yes	1	5
C_{14}	Proximity to existing berths (**existingB**)	Whole number: 1 - No; 5 - Yes	1	4

C_{15}	Elements of the environment (Environmental network Natura 2000) (**environment**)	Whole number: 1 - No; 5 - Yes	1	5
C_{16}	Harm from anchoring a vessel to the holding ground (**harmfulness**)	Whole number: 1 - No; 5 - Yes	1	5
C_{17}	Archaeological sites (**sites**)	Whole number; 1 - No; 5 - Yes	1	5

The solutions for all applied methods were obtained using the programming language R in order to select the best location of the nautical anchorage in the area of SDC.

Several criteria are defined for each of the methods, specifically:

C1: Surface of the field of the future anchorage in square meters;

C2: Surface of the bay in square meters;

C3: Share of the field surface in relation to the surface of the bay in square meters (in %).

C4: Protection / Unprotection of the bay (1 - Protected; 5 - Partially protected; 9 - Unprotected);

C5: Distance from the coast in meters;

C6: Field number;

C7: Presence of maritime traffic (if the proximity of the main traffic routes is less than 500 m; 1 - Yes; 5 - No);

C8: Presence of an official anchorage (1 - Yes; 5 - No);

C9: Presence of underwater cables and pipelines (Proximity of cables and pipelines less than 500 m; 1 - Yes; 5 - No);

C10: Risk of collision (1 - negligible; 2 - small; 3 - medium; 4 - large; 5 - very large);

C11: Depth (1 - Satisfactory; 5 - Unsatisfactory);

C12: Tide level and existence of sea currents (1 - small; 3 - medium; 5 - large);

C13: Proximity to the public ports (1 - No; 5 - Yes);

C14: Proximity to the existing berths (1 - No; 5 - Yes);

C15: Environmental elements (Environmental network Natura 2000; 1 - No; 5 - Yes);

C16: Harm from anchoring a vessel to the holding ground (1 - No; 5 - Yes)

C17: Archaeological sites (1 - No; 5 - Yes)

Each criterion is given an importance rating on a scale from 1 to 13 (rating 13 for the most important criterion and 1 for the lowest criterion).

Therefore, the weight values of the criteria (with the TOPSIS and PROMETHEE II methods) are: For C1: **5**; for C2: **4**; for C3: **9**; for C4: **13**; for C5: **3.5**; C6: **1**; for C7: **1**; for C8: **1**; for C9: **1**; for C10: **1**; for C11: **1**; C12: **9**; for C13: **1**; for C14: 1; C15: **2**; C16: **2**; for C17: **1**.

For each criterion, there are eighty-six variants, i.e. fields in bays, which are described in detail with tables showing the input data (previous chapter 6.1).

Taking into account the SDC's spatial plan, fifty-six locations were taken as an example, and a total of eighty-six fields at the described locations are shown in the Table 18.

The criteria for selecting the twenty best areas for setting up nautical anchorages in the area of SDC include: Surface of the nautical anchorage field (C1); Bay surface (C2); Percentage share of the field surface in the bay surface (C3); Protection/partial protection and lack of protection of the bay from wind, waves and sea currents (C4); Distance from the coast (C5); Number of fields in the location (C6); Presence of maritime traffic (C7); Presence of an official anchorage (C8); Presence of underwater cables and pipelines (C9); Risk of collision (10); Depth (C11); Tide level and existence of sea currents (C12); Proximity to the public ports (C13); Proximity to the existing moorings (C14); Environmental elements (Ecological network Natura 2000) (C15); Damage from anchoring a vessel to the seabed (C16); and Archaeological sites (C17).

6.3 Settings and solution procedures for AHP, TOPSIS, AHP-TOPSIS-2N and PROMETHEE II

Each of the selected locations has its own characteristics that need to be taken into account in order to determine the values of the weighting coefficients of the criteria.

Ten of the 17 available criteria were taken for analysis when applying the AHP and AHP-TOPSIS-2N methods (considering that when calculating the relationship between the criteria and creating a consistent matrix, it is possible to use a maximum of ten criteria).

In TOPSIS and PROMETHEE II, the number of the analysed criteria is seventeen. Table 37 shows the criteria label, name, expected effect, and unit of measure. The layout of the relationship and the importance of each criterion based on Saaty's scale in the AHP method are shown in Table 38.

Table 37. Criteria design specification for AHP and the AHP-TOPSIS-2N method

Label	Criterion / (name of criteria in the tables)	Expected effect	Unit of measure
C1	Field area (surfaceF)	Surface maximisation	Square meters

C2	The surface of the bay (surfaceB)	Maximised bay area	Square meters
C3	Percentage share of field area/Bay area (percentage)	Maximised share of the field area in the bay area	Percentage
C4	Closure/Openness of the bay (protection)	Minimise the openness of the bay	Number
C5	Distance from the coast (distance)	Maximise the distance from the coast	Meters
C6	Field number (numberF)	Minimisation	Number
C7	Tide level and existence of sea currents (tides)	Minimisation	Number
C8	Environmental elements (environmental network Natura 2000) (environment)	Minimisation	Number
C9	Damage from anchoring a vessel to the holding ground (harmfulness)	Minimisation	Number
C10	Archaeological sites (sites)	Minimisation	Number

Table 38. Relationship between criteria according to the Saaty scale in AHP method

	Criterion name	surfaceF	surfaceB	percentage	protection	distance	number F	tide	environment	harmfulness	sites
Criterion name	Designation	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
surfaceF	C1	1	1	1	1	2	6	1/2	2	2	5
surfaceB	C2	1	1	1	1	1	5	1/2	2	2	4

percentage	C3	1	1	1	4	2	7	5	3	3	4
protection	C4	1	1	1/4	1	1	7	2	5	5	5
distance	C5	1/2	1	1/2	1	1	4	3	2	2	3
numberF	C6	1/6	1/5	1/7	1/7	1/4	1	1/9	1/2	1/2	1
tide	C7	2	2	1/5	1/2	1/3	9	1	4	4	9
environment	C8	1/2	1/2	1/3	1/5	1/2	2	1/4	1	1	2
harmfulness	C9	1/2	1/2	1/3	1/5	1/2	2	1/4	1	1	3
site	C10	1/5	1/4	1/4	1/5	1/3	1	1/9	1/2	1/3	1

Table 39 shows the input data, i.e. the values of the decision matrix for the ten most important criteria when applying the AHP method of MCDM.

Table 39. Decision matrix when applying the AHP and AHP-TOPSIS-2N method

No	surfaceF	surfaceB	percentage	protection	distance	numberF	tide	environment	harmfulness	site
1	2,059.39	723,767.14	0.3	5	3.9	3	1	5	5	1
2	17,781.05	723,767.14	2.5	5	24.3	3	1	5	5	1
3	6,744.95	723,767.14	0.9	5	24	3	1	5	5	1
4	3,416.15	11,800.58	28.9	9	12.4	1	1	5	5	1
5	5,176.56	227,733.31	2.3	5	2.7	1	1	5	5	1
6	7,756.37	64,415.18	12	5	15.2	1	1	5	5	1
7	5,990.29	71,424.38	8.4	5	15.8	2	1	5	5	1
8	2,400.00	71,424.38	3.4	5	0	2	1	5	5	1
9	12,634.41	153,538.63	8.2	1	4.4	2	1	1	1	1
10	9,900.11	153,538.63	6.4	1	13.1	2	1	1	1	1
11	15,056.05	100,294.43	15	9	7.4	2	1	1	1	1
12	13,771.01	100,294.43	13.7	9	14.4	2	1	5	5	1
13	5,495.04	31,664.56	17.4	1	4.6	1	1	1	1	1
14	3,457.25	46,398.67	7.5	9	11.9	1	1	1	1	1
15	73,429.68	438,906.63	16.7	1	81.2	1	1	1	1	1
16	4,792.32	641,244.47	0.7	1	37.4	2	1	5	5	1
17	16,925.83	641,244.47	2.6	1	26.3	2	1	5	5	1
18	5,997.74	22,357.42	26.8	5	6.6	1	1	5	5	1
19	8,020.14	63,252.47	12.7	5	9.6	1	1	1	1	1
20	3,842.70	23,054.82	16.7	5	8.7	1	1	1	1	1
21	5,951.07	46,591.92	12.8	5	27	1	1	1	1	1

22	9,962.35	92,965.25	10.7	5	48.5	1	1	1	1	1
23	3,893.59	14,370.81	27.1	5	21.4	1	1	1	1	1
24	7,561.37	368,850.39	2	5	50.2	3	1	5	5	1
25	7,561.51	368,850.39	2.1	5	42.4	3	1	5	5	1
26	12,031.56	368,850.39	3.3	5	24.8	3	1	5	5	1
27	9,797.21	381,807.85	2.6	1	11.4	2	1	1	1	1
28	19,119.20	381,807.85	5	1	60.9	2	1	1	1	1
29	4,967.51	365,276.02	1.4	5	13.4	3	1	5	5	1
30	11,327.23	365,276.02	3.1	5	14.8	3	1	5	5	5
31	5,369.64	365,276.02	1.5	5	5.8	3	1	5	5	1
32	18,908.51	64,407.48	29.4	9	48.4	1	1	1	1	1
33	16,416.96	83,076.61	19.8	5	44.9	1	1	1	1	1
34	76,654.37	339,484.25	22.6	9	76.5	1	1	1	1	1
35	12,189.12	158,135.45	7.7	5	18.1	2	1	5	5	1
36	29,040.95	158,135.45	18.4	5	9.8	2	1	5	5	1
37	18,809.22	55,958.72	33.6	5	10.5	1	1	5	5	1
38	28,014.56	129,531.52	21.6	5	11.9	2	1	5	5	1
39	5,653.71	129,531.52	4.4	5	4.7	2	1	5	5	1
40	19,045.87	270,860.78	7	1	7	2	1	5	5	1
41	39,759.11	270,860.78	14.7	1	5.2	2	1	5	5	1
42	33,300.56	172,777.22	19.3	1	15.6	2	1	5	5	1
43	20,184.50	172,777.22	11.7	1	6.2	2	1	5	5	1
44	15,461.52	232,623.14	6.6	1	27.1	4	5	5	5	1
45	19,223.69	232,623.14	8.3	1	29.2	4	5	5	5	1
46	11,217.76	232,623.14	4.8	1	7.4	4	5	5	5	1
47	4,294.60	232,623.14	1.8	1	8.2	4	5	5	5	1
48	9,019.93	42,964.85	21	9	38.7	1	1	1	1	1
49	4,173.73	89,446.05	4.7	5	11.9	3	1	5	5	1
50	2,048.41	89,446.05	2.3	5	18.7	3	1	5	5	1
51	5,841.32	89,446.05	6.5	5	10.2	3	1	5	5	1
52	8,387.75	143,621.11	5.8	5	5.7	4	1	5	5	1
53	5,235.86	143,621.11	3.6	5	8.6	4	1	5	5	1
54	3,112.82	143,621.11	2.2	5	6.2	4	1	5	5	1
55	7,322.86	143,621.11	5.1	5	6.4	4	1	5	5	1
56	4,663.32	63,348.89	7.4	5	5.9	2	1	5	5	1
57	5,908.71	63,348.89	9.3	5	3.1	2	1	5	5	1
58	1,585.75	17,635.17	9	9	19.2	1	1	5	5	1
59	1,649.94	24,401.10	6.8	9	21.6	2	1	5	5	1
60	2,601.84	24,401.10	10.7	9	9.1	2	1	5	5	1
61	2,793.77	32,982.85	8.5	5	21.8	1	1	5	5	1
62	2,998.57	68,871.31	4.4	5	31	2	1	5	5	1

63	3,301.45	68,871.31	4.8	5	42.7	2	1	5	5	1
64	9,075.05	43,204.52	21	5	9.7	2	1	5	5	1
65	2,204.46	43,204.52	5.1	5	15.6	2	1	5	5	1
66	2,911.78	26,374.64	11	5	10.5	1	1	5	5	1
67	21,759.24	215,264.65	10.1	9	13.5	1	1	5	5	1
68	6,947.12	96,286.36	7.2	1	9.6	2	1	5	5	1
69	900.00	96,286.36	0.9	1	8.1	2	1	5	5	1
70	3,540.92	19,984.43	17.7	5	4.4	1	1	5	5	1
71	3,950.60	89,259.53	4.4	1	7.8	1	1	5	5	1
72	3,698.50	130,729.53	2.8	5	10.5	1	1	5	5	1
73	17,977.06	192,140.53	9.4	9	24.5	1	1	5	5	1
74	16,066.28	75,178.13	21.4	5	23.2	1	1	5	5	1
75	22,435.02	124,493.66	18	1	50.9	1	1	1	1	1
76	5,929.95	79,469.29	7.5	9	27.2	1	1	5	5	1
77	19,034.87	48,094.56	39.6	9	8.7	1	1	5	5	1
78	22,354.01	190,158.53	11.8	1	8.1	1	1	5	5	1
79	13,268.09	77,017.13	17.2	1	12.3	1	1	5	5	1
80	9,156.65	98,277.88	9.3	1	20	1	1	5	5	1
81	8,473.78	140,579.16	6	5	21.9	2	1	5	5	1
82	4,936.84	140,579.16	3.5	5	3.1	2	1	5	5	1
83	10,809.48	50,893.55	21.2	5	14	1	1	5	5	1
84	7,897.21	95,881.30	8.2	5	1.9	1	1	5	5	1
85	4,375.82	91,277.43	4.8	1	12.3	2	1	5	5	1
86	6,871.98	91,277.43	7.5	1	11	2	1	5	5	1

The values of the maximum eigenvalue λ_{max}, the Consistency Ratio (*CI*) and the Consistency Index (*CR*) in the AHP method are shown in Table 40.

Table 40. The values of the maximum own value λ_{max}, Consistency Index (*CI*) and Consistency Ratio (*CR*) obtained using the AHP method

λ_{max}	11.2671
CI	0.14079
CR	0.09449

Given that the consistency index (CR value from the formula (*5.3.9*) shown in Table 40 is 0.09449), less than 10%, it is considered that a good relationship between the criteria has been established.

Table 41 shows the values of the random index of consistency depending on a number of criteria. For the number of criteria equal to ten, this index has a value of 1.49.

Table 41. Values of the random index of consistency for the defined number of criteria

Number of criteria	1	2	3	4	5	6	7	8	9	**10**
RCI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	**1.49**

Table 42 shows the input values of the elements: criteria names, the target vector p_i and the vector of criteria weight values that were applied to the AHP-TOPSIS-2N MCDM method.

Table 42. Relationship between criteria according to the Saaty scale (AHP) and elements of the target vector in the AHP-TOPSIS-2N

	Criterion name	surfaceF	surfaceB	percentage	protection	distance	number F	tide	environment	harmfulness	sites
Criterion name	**Designation**	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
surfaceF	C1	1	1	1	1	2	6	1/2	2	2	5
surfaceB	C2	1	1	1	1	1	5	1/2	2	2	4
percentage	C3	1	1	1	4	2	7	5	3	3	4
protection	C4	1	1	1/4	1	1	7	2	5	5	5
distance	C5	1/2	1	1/2	1	1	4	3	2	2	3
numberF	C6	1/6	1/5	1/7	1/7	1/4	1	1/9	1/2	1/2	1
tide	C7	2	2	1/5	1/2	1/3	9	1	4	4	9
environment	C8	1/2	1/2	1/3	1/5	1/2	2	1/4	1	1	2
harmfulness	C9	1/2	1/2	1/3	1/5	1/2	2	1/4	1	1	3
site	C10	1/5	1/4	1/4	1/5	1/3	1	1/9	1/2	1/3	1
Criteria label		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Goal vector	p_i	**max**	**max**	**max**	**min**	**max**	**min**	**min**	**min**	**min**	**min**

Table 43. Criteria design specification for the TOPSIS I PROMETHEE II method of MCA

Label	Criterion name	Expected effect	Measure unit
C1	Field surface (**surfaceF**)	Surface maximisation	Square meters
C2	Area of the bay (**surfaceB**)	Maximised bay surface	Square meters
C3	The percentage of the field area in the bay area (**percentage**)	Maximised share of the field surface in the bay surface	Percentage
C4	Protection of the bay (**protection**)	Minimise the unprotection of the bay	Number
C5	Distance from the coast (**distance**);	Maximise the distance from the coast	Meters in length
C6	Number of anchorage fields in the bay (**numberF**)	minimisation	Number
C7	Existence of maritime traffic (**traffic**)	minimisation	Number
C8	Existence of an official anchorage (**anchorage**)	minimisation	Number
C9	Existence of underwater cables and pipelines (**cables**)	minimisation	Number
C10	Risk of collision (**danger**)	minimisation	Number
C11	Depth (**depth**)	minimisation	Number
C12	Tide level and existence of sea currents (**tide**)	minimisation	Number
C13	Proximity to public ports (**proximityP**)	minimisation	Number
C14	Proximity to existing berths (**existingB**)	minimisation	Number
C15	Elements of the environment (Environmental network Natura 2000) (**environment**)	minimisation	Number
C16	Harm from anchoring a vessel to the seabed (**harmfulness**)	minimisation	Number
C17	Archaeological sites (**sites**)	minimisation	Number

Table 44. Elements of the goal vector and their weight values when applying TOPSIS and PROMETHEE II methods of MCA

TOPSIS PROMETHEE2	**Criterion name**	**Goal vector**	**Vector of weighting coefficients**
Criterion / (name of criteria in the tables)	**Label**	p_i	w_i
Field surface (**surfaceF**)	C1	max	5

Area of the bay (**surfaceB**)	C2	max	4
The percentage of the field area in the bay area (**percentage**)	C3	max	9
Protection of the bay (1. Protected; 5: Partially protected; 9: Not protected) (**protection**)	C4	min	13
Distance from the coast (**distance**)	C5	max	3.5
Number of anchorage fields in the bay (**numberF**)	C6	min	1
Presence of maritime traffic (**traffic**)	C7	min	1
Presence of an official anchorage (**anchorage**)	C8	min	1
Presence of underwater cables and pipelines (**cables**)	C9	min	1
Risk of collision (**danger**)	C10	min	1
Depth (**depth**);	C11	max	1
Tide level and existence of sea currents (**tide**)	C12	min	9
Proximity to public ports (**proximityP**)	C13	min	1
Proximity to the existing berths (**existingB**)	C14	min	1
Elements of the environment (Environmental network Natura 2000) (**environment**)	C15	min	2
Harm from anchoring a vessel to the holding ground (**harmfulness**)	C16	min	2
Archaeological sites (**sites**)	C17	min	1

The decision matrix for eighty-six locations in the application of the TOPSIS and PROMETHEE II MCDM method is presented by the data found in Table 45 with the criteria whose values follow the **No** (ordinal number) indicated in the first column:

1. Serial number of the location (**No**)
2. Location name (**Name**)
3. Island (**Island**)
4. The name of the field in the bay (**field**)
5. Field surface (**surfaceF**);
6. Surface of the bay (**surfaceB**);
7. The percentage of the field surface in the bay area (**percentage**);
8. Protection of the bay (1. Protected; 5: Partially protected; 9: Not protected) (**protection**);

9. Distance from the coast (**distance**);
10. Number of anchorage fields in the bay (**numberF**);
11. Presence of maritime traffic (**traffic**);
12. Presence of an official anchorage (**anchorage**);
13. Presence of underwater cables and pipelines (**cables**);
14. Risk of collision (**danger**);
15. Depth (**depth**);
16. Tide level and existence of sea currents (**tide**);
17. Proximity to public ports (**proximityP**);
18. Proximity to the existing berths (**existingB**);
19. Elements of the environment (Environmental network Natura 2000) (**environment**);
20. Harm from anchoring a vessel to the holding ground (**harmfulness**);
21. Archaeological sites (**site**).

Table 45. Decision matrix when applying the AHP and AHP-TOPSIS-2N methods

No	surfaceF	surfaceB	percentage	protection	distance	numberF	traffic	anchorage	cables	danger	depth	tide	proximityP	existingB	environment	harmfulness	site
1	2,059.39	723,767.14	0.3	5	3.9	3	1	1	1	3	5	1	1	1	5	5	1
2	17,781.05	723,767.14	2.5	5	24.3	3	1	1	1	3	5	1	1	1	5	5	1
3	6,744.95	723,767.14	0.9	5	24	3	1	1	1	3	5	1	1	1	5	5	1
4	3,416.15	11,800.58	28.9	9	12.4	1	1	1	1	3	5	1	1	1	5	5	1
5	5,176.56	227,733.31	2.3	5	2.7	1	1	1	1	3	5	1	1	1	5	5	1
6	7,756.37	64,415.18	12.0	5	15.2	1	1	1	1	3	5	1	1	1	5	5	1
7	5,990.29	71,424.38	8.4	5	15.8	2	1	1	1	3	5	1	1	1	5	5	1
8	2,400.00	71,424.38	3.4	5	0	2	1	1	1	3	5	1	1	1	5	5	1
9	12,634.41	153,538.63	8.2	1	4.4	2	1	1	1	3	5	1	1	1	1	1	1
10	9,900.11	153,538.63	6.4	1	13.1	2	1	1	1	3	5	1	1	1	1	1	1
11	15,056.05	100,294.43	15.0	9	7.4	2	1	1	1	3	5	1	1	1	1	1	1
12	13,771.01	100,294.43	13.7	9	14.4	2	1	1	1	3	5	1	1	1	5	5	1
13	5,495.04	31,664.56	17.4	1	4.6	1	1	1	1	3	5	1	1	1	1	1	1
14	3,457.25	46,398.67	7.5	9	11.9	1	1	1	1	3	5	1	1	1	1	1	1
15	73,429.68	438,906.63	16.7	1	81.2	1	1	1	1	3	5	1	1	1	1	1	1
16	4,792.32	641,244.47	0.7	1	37.4	2	1	1	1	3	5	1	1	1	5	5	1
17	16,925.83	641,244.47	2.6	1	26.3	2	1	1	1	3	5	1	1	1	5	5	1
18	5,997.74	22,357.42	26.8	5	6.6	1	1	1	1	3	5	1	1	1	5	5	1
19	8,020.14	63,252.47	12.7	5	9.6	1	1	1	1	3	5	1	1	1	1	1	1
20	3,842.70	23,054.82	16.7	5	8.7	1	1	1	1	3	5	1	1	1	1	1	1
21	5,951.07	46,591.92	12.8	5	27	1	1	1	1	3	5	1	1	1	1	1	1

22	9,962.35	92,965.25	10.7	5	48.5	1	1	1	1	3	5	1	1	1	1	1	1
23	3,893.59	14,370.81	27.1	5	21.4	1	1	1	1	3	5	1	1	1	1	1	1
24	7,561.37	368,850.39	2.0	5	50.2	3	1	1	1	3	5	1	1	1	5	5	1
25	7,561.51	368,850.39	2.1	5	42.4	3	1	1	1	3	5	1	1	1	5	5	1
26	12,031.56	368,850.39	3.3	5	24.8	3	1	1	1	3	5	1	1	1	5	5	1
27	9,797.21	381,807.85	2.6	1	11.4	2	1	1	1	3	5	1	1	1	1	1	1
28	19,119.20	381,807.85	5.0	1	60.9	2	1	1	1	3	5	1	1	1	1	1	1
29	4,967.51	365,276.02	1.4	5	13.4	3	1	1	1	3	5	1	1	1	5	5	1
30	11,327.23	365,276.02	3.1	5	14.8	3	1	1	1	3	5	1	1	1	5	5	5
31	5,369.64	365,276.02	1.5	5	5.8	3	1	1	1	3	5	1	1	1	5	5	1
32	18,908.51	64,407.48	29.4	9	48.4	1	1	1	1	3	5	1	1	1	1	1	1
33	16,416.96	83,076.61	19.8	5	44.9	1	1	1	1	3	5	1	1	1	1	1	1
34	76,654.37	339,484.25	22.6	9	76.5	1	1	1	1	3	5	1	1	1	1	1	1
35	12,189.12	158,135.45	7.7	5	18.1	2	1	1	1	3	5	1	1	1	5	5	1
36	29,040.95	158,135.45	18.4	5	9.8	2	1	1	1	3	5	1	1	1	5	5	1
37	18,809.22	55,958.72	33.6	5	10.5	1	1	1	1	3	5	1	1	1	5	5	1
38	28,014.56	129,531.52	21.6	5	11.9	2	1	1	1	3	5	1	1	1	5	5	1
39	5,653.71	129,531.52	4.4	5	4.7	2	1	1	1	3	5	1	1	1	5	5	1
40	19,045.87	270,860.78	7.0	1	7	2	1	1	1	3	5	1	1	1	5	5	1
41	39,759.11	270,860.78	14.7	1	5.2	2	1	1	1	3	5	1	1	1	5	5	1
42	33,300.56	172,777.22	19.3	1	15.6	2	1	1	1	3	5	1	1	1	5	5	1
43	20,184.50	172,777.22	11.7	1	6.2	2	1	1	1	3	5	1	1	1	5	5	1
44	15,461.52	232,623.14	6.6	1	27.1	4	5	1	1	5	5	5	1	1	5	5	1
45	19,223.69	232,623.14	8.3	1	29.2	4	5	1	1	5	5	5	1	1	5	5	1
46	11,217.76	232,623.14	4.8	1	7.4	4	5	1	1	5	5	5	1	1	5	5	1
47	4,294.60	232,623.14	1.8	1	8.2	4	5	1	1	5	5	5	1	1	5	5	1
48	9,019.93	42,964.85	21.0	9	38.7	1	1	1	5	3	5	1	1	1	1	1	1
49	4,173.73	89,446.05	4.7	5	11.9	3	1	1	1	3	5	1	1	1	5	5	1
50	2,048.41	89,446.05	2.3	5	18.7	3	1	1	1	3	5	1	1	1	5	5	1
51	5,841.32	89,446.05	6.5	5	10.2	3	1	1	1	3	5	1	1	1	5	5	1
52	8,387.75	143,621.11	5.8	5	5.7	4	1	1	1	3	5	1	1	1	5	5	1
53	5,235.86	143,621.11	3.6	5	8.6	4	1	1	1	3	5	1	1	1	5	5	1
54	3,112.82	143,621.11	2.2	5	6.2	4	1	1	1	3	5	1	1	1	5	5	1
55	7,322.86	143,621.11	5.1	5	6.4	4	1	1	1	3	5	1	1	1	5	5	1
56	4,663.32	63,348.89	7.4	5	5.9	2	1	1	1	3	5	1	1	1	5	5	1
57	5,908.71	63,348.89	9.3	5	3.1	2	1	1	1	3	5	1	1	1	5	5	1
58	1,585.75	17,635.17	9.0	9	19.2	1	1	1	1	3	5	1	1	1	5	5	1
59	1,649.94	24,401.10	6.8	9	21.6	2	1	1	1	3	5	1	1	1	5	5	1
60	2,601.84	24,401.10	10.7	9	9.1	2	1	1	1	3	5	1	1	1	5	5	1
61	2,793.77	32,982.85	8.5	5	21.8	1	1	1	1	3	5	1	1	1	5	5	1
62	2,998.57	68,871.31	4.4	5	31	2	1	1	1	3	5	1	1	1	5	5	1
63	3,301.45	68,871.31	4.8	5	42.7	2	1	1	1	3	5	1	1	1	5	5	1
64	9,075.05	43,204.52	21.0	5	9.7	2	1	1	1	3	5	1	1	1	5	5	1
65	2,204.46	43,204.52	5.1	5	15.6	2	1	1	1	3	5	1	1	1	5	5	1
66	2,911.78	26,374.64	11.0	5	10.5	1	1	1	1	3	5	1	1	1	5	5	1
67	21,759.24	215,264.65	10.1	9	13.5	1	1	1	1	3	5	1	1	1	5	5	1
68	6,947.12	96,286.36	7.2	1	9.6	2	1	1	1	3	5	1	1	1	5	5	1
69	900.00	96,286.36	0.9	1	8.1	2	1	1	1	3	5	1	1	1	5	5	1

70	3,540.92	19,984.43	17.7	5	4.4	1	1	1	1	3	5	1	1	1	5	5	1
71	3,950.60	89,259.53	4.4	1	7.8	1	1	1	1	3	5	1	1	1	5	5	1
72	3,698.50	130,729.53	2.8	5	10.5	1	1	1	1	3	5	1	1	1	5	5	1
73	17,977.06	192,140.53	9.4	9	24.5	1	1	1	1	3	5	1	1	1	5	5	1
74	16,066.28	75,178.13	21.4	5	23.2	1	1	1	1	3	5	1	1	1	5	5	1
75	22,435.02	124,493.66	18.0	1	50.9	1	1	1	1	3	5	1	1	1	1	1	1
76	5,929.95	79,469.29	7.5	9	27.2	1	1	1	1	4	5	1	1	5	5	5	1
77	19,034.87	48,094.56	39.6	9	8.7	1	1	1	1	3	5	1	1	1	5	5	1
78	22,354.01	190,158.53	11.8	1	8.1	1	1	1	1	3	5	1	1	1	5	5	1
79	13,268.09	77,017.13	17.2	1	12.3	1	1	1	1	3	5	1	1	1	5	5	1
80	9,156.65	98,277.88	9.3	1	20	1	1	1	1	3	5	1	1	1	5	5	1
81	8,473.78	140,579.16	6.0	5	21.9	2	1	1	1	3	5	1	1	1	5	5	1
82	4,936.84	140,579.16	3.5	5	3.1	2	1	1	1	3	5	1	1	1	5	5	1
83	10,809.48	50,893.55	21.2	5	14	1	1	1	1	3	5	1	1	1	5	5	1
84	7,897.21	95,881.30	8.2	5	1.9	1	1	1	1	3	5	1	1	1	5	5	1
85	4,375.82	91,277.43	4.8	1	12.3	2	1	1	1	3	5	1	1	1	5	5	1
86	6,871.98	91,277.43	7.5	1	11	2	1	1	1	3	5	1	1	1	5	5	1

6.4. Results

On the basis of the collected data on eighty-six locations of nautical anchorages, which in this case study represents a decision-making matrix, 10 criteria were defined using AHP and AHP-TOPSIS-2N and 17 using TOPSIS and PROMETHEE II methods; their weights and goals for each criterion were determined by applying four different methods of MCA; the obtained solutions and their interpretation are given in this chapter of the doctoral dissertation.

Note: Since the R language cannot work using Croatian diacritic characters "*ž*", "*Ž*", "*š*", "*Š*", "*đ*", "*Đ*", "*č*", "*Č*", "*ć*" and "*Ć*", hereafter the names of the locations of nautical anchorages, as well as the names of the islands containing these letters will be used in such a way that these Croatian diacritic characters will be replaced by the letters "*z*", "*Z*", "*s*", "*S*", "*d*", "*D*", "*c*", "*C*", "*c*" and "*C*".

6.4.1. Results of the AHP method

Table 46 displays the first twenty-five best locations of the selected nautical anchorages obtained by the AHP method of MCA. The first column of Table 46 represents the serial number of the location from Table 14; while the last column represents the order, rank. For example, locations Marina Uvala Miline, located at the east coast of Oštrica mala on Čiovo Island, Drvenik Island, Šolta Island and the mainland have the greatest influence and take the first places in the table, i.e. these are the best locations for setting up nautical anchorage sites in the area of Split-Dalmatia County.

Table 46. Presentation of the best twenty-five locations of nautical anchorages obtained by the AHP method of MCA, with a presentation of the order value and rank

No	Name	Island	score AHP	Rank AHP
15	MARINA Uvala Miline - Eastern coast Ostrica mala	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.832327588	1
34	DRVENIK MALI Uvala Vela Rina	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.717805187	2
75	HVAR Uvala Pribinja	HVAR	0.664242706	3
28	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.633467001	4
32	OKRUG GORNJI Uvala Duboka	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.575918613	5
42	HVAR Uvala Vinogradisce	HVAR	0.558053342	6
13	SUTIVAN Uvala Vica	BRAC	0.555391086	7
41	HVAR Uvala Tarsce	HVAR	0.54608824	8
27	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.538141018	9
33	OKRUG GORNJI Zaljev Saldun, Punta Rozac	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.533055974	10
17	OKRUG GORNJI Uvala Sveta Fumija	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.531446832	11
9	PUCISCA Luka Pucisce	BRAC	0.52745379	12
10	PUCISCA Luka Pucisce	BRAC	0.525466097	13
16	OKRUG GORNJI Uvala Sveta Fumija	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.516446823	14
23	SOLTA Uvala Necujam - Tiha uvala	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.507638996	15
79	VIS Uvala Stoncica - Uvala Vela Cavojnica	VIS	0.505913008	16
78	VIS Uvala Stoncica	VIS	0.504525244	17
48	HVAR Uvala Mala Milna	HVAR	0.499641169	18
77	VIS Budikovac	VIS	0.493449871	19
43	HVAR Uvala Vinogradisce	HVAR	0.484106499	20
22	SOLTA Uvala Necujam - Uvala Supetar	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.481857819	21
37	HVAR Luka Soline - west	HVAR	0.47868848	22

40	HVAR Uvala Tarsce	HVAR	0.474357365	23
80	KOMIZA Bisevska luka	VIS	0.471817179	24
20	SOLTA Uvala Necujam - Uvala Potkamenica	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.437690906	25

6.4.2. Results of the TOPSIS method

Table 47 presents the first twenty-five best locations of nautical anchorages obtained by the TOPSIS method of MCA. No. (column 1 of Table 47) stands for the serial number of the location from Table 14, while the last column represents the order, i.e. rank.

Table 47. The best twenty-five locations of nautical anchorages obtained by the TOPSIS method of the MCA, with a display of rank

No	Name	Island	Score TOPSIS	Rank TOPSIS
15	MARINA Uvala Miline - Eastern coast Ostrica mala	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.724346575	1
34	DRVENIK MALI Uvala Vela Rina	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.621553767	2
42	HVAR Uvala Vinogradisce	HVAR	0.61128107	3
75	HVAR Uvala Pribinja	HVAR	0.597699642	4
41	HVAR Uvala Tarsce	HVAR	0.597643544	5
37	HVAR Luka Soline - west	HVAR	0.587403836	6
38	HVAR Stipanska uvala	HVAR	0.556354372	7
77	VIS Budikovac	VIS	0.551245114	8
79	VIS Uvala Stoncica - Uvala Vela Cavojnica	VIS	0.550544036	9
78	VIS Uvala Stoncica	VIS	0.545083421	10
36	HVAR Luka Soline - Uvala Prevojice	HVAR	0.541223806	11
28	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.539757511	12
43	HVAR Uvala Vinogradisce	HVAR	0.538712479	13
33	OKRUG GORNJI Zaljev Saldun, Punta Rozac	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.538014799	14
23	SOLTA Uvala Necujam - Tiha uvala	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.533211029	15
74	HVAR Uvala V. Zarace	HVAR	0.532554615	16
13	SUTIVAN Uvala Vica	BRAC	0.532237587	17
32	OKRUG GORNJI Uvala Duboka	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.531495438	18

18	OKRUG GORNJI Uvala Pircina	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.527842895	19
17	OKRUG GORNJI Uvala Sveta Fumija	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.52156052	20
40	HVAR Uvala Tarsce	HVAR	0.51992934	21
83	VIS Srebrna	VIS	0.515512859	22
80	KOMIZA Bisevska luka	VIS	0.511116893	23
9	PUCISCA Luka Pucisce	BRAC	0.509581825	24
64	Uvala Tiha - Veli Dolac	HVAR	0.508510709	25

Even though the result, i.e. the order of the best locations of nautical anchorages determined by the TOPSIS method, is not identical to the order obtained by the AHP method, most of the best, i.e. nineteen out of twenty-five locations obtained by the TOPSIS method of MCA, coincide with the list of the best obtained by the AHP method.

With the order of the best twenty-five nautical anchorages obtained by the AHP method, the results realised by the TOPSIS method do not match the locations marked with numbers: 38, 36, 74, 18, 83, and 64.

The reason for such a slight deviation is mostly reflected in the difference in the calculation procedure of the AHP and TOPSIS methods of MCA, the difference that was established by setting the relationship between the criteria, but also in the number of criteria that these two methods analyse and consider.

The most complicated part of the AHP method application is the creation of a consistent decision matrix. In addition, it is the establishment of a consistent relationship between the criteria. This is very difficult to achieve with ten criteria.

6.4.3. Results of the AHP-TOPSIS-2N method

Table 48 presents the value of the Consistency Index with the AHP-TOPSIS-2N method, while Table 49 shows the list of the finest 25 locations of nautical anchorages obtained by the combined AHP-TOPSIS-2N.

Even though the result, the order of the best locations of nautical anchorages determined by the AHP-TOPSIS-2N method of MCA is not identical to the order established by the AHP method, the first 21 locations identified by the hybrid AHP-TOPSIS-2N method coincide with the AHP method of MCA. The results also indicate that the order of the first twenty-five locations determined by the AHP-TOPSIS-2N method does not match. The list of the most valuable locations obtained by the AHP-TOPSIS-2N method does not include the locations marked with ordinal numbers 38, 18, 74 and 36, because they are not in the list of the first 25 locations determined by the AHP method.

Table 48 displays the value of the Consistency Index (*CR*) of the AHP-TOPSIS-2N method.

Table 48. Values of the Consistency Index (CR) of the AHP-TOPSIS-2N method

CR	**0.096680424**

Table 49. The most desirable twenty-five locations of nautical anchorages obtained by the AHP-TOPSIS-2N method of the multi-criteria method, with the rank indication

No	Name	Island	Score AHP-TOPSIS-2N	Rank AHP-TOPSIS-2N
15	MARINA Uvala Miline - Eastern coast Ostrica mala	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.699889269	1
34	DRVENIK MALI Uvala Vela Rina	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.589832527	2
75	HVAR Uvala Pribinja	HVAR	0.579814562	3
42	HVAR Uvala Vinogradisce	HVAR	0.544088478	4
28	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.53225541	5
37	HVAR Luka Soline - west	HVAR	0.530797326	6
41	HVAR Uvala Tarsce	HVAR	0.526133631	7
33	OKRUG GORNJI Zaljev Saldun, Punta Rozac	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.514254146	8
32	OKRUG GORNJI Uvala Duboka	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.511230797	9
23	SOLTA Uvala Necujam - Tiha uvala	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.511113226	10
13	SUTIVAN Uvala Vica	BRAC	0.503992407	11
77	VIS Budikovac	VIS	0.503981718	12
79	VIS Uvala Stoncica - Uvala Vela Cavojnica	VIS	0.496976793	13
17	OKRUG GORNJI Uvala Sveta Fumija	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.490374251	14
78	VIS Uvala Stoncica	VIS	0.485869986	15
38	HVAR Stipanska uvala	HVAR	0.482751521	16
43	HVAR Uvala Vinogradisce	HVAR	0.479135519	17
16	OKRUG GORNJI Uvala Sveta Fumija	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.478861082	18
9	PUCISCA Luka Pucisce	BRAC	0.476875495	19

18	OKRUG GORNJI Uvala Pircina	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.473684816	20
27	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	0.473317616	21
10	PUCISCA Luka Pucisce	BRAC	0.47225439	22
74	HVAR Uvala V. Zarace	HVAR	0.471952728	23
36	HVAR Luka Soline - Uvala Prevojice	HVAR	0.46495083	24
40	HVAR Uvala Tarsce	HVAR	0.464924159	25

Likewise, the results obtained by AHP-TOPSIS-2N do not match the results obtained by the TOPSIS method in only 3 of the 25 best locations, considering that the locations marked with ordinal numbers 16, 27 and 10, which were in the list of the best obtained by TOPSIS methods, were not recognised as the best even by the hybrid AHP-TOPSIS-2N MCA method, as can be seen in Table 50.

6.4.4. Results of the PROMETHEE II method

Table 50 presents the first twenty-five best locations of nautical anchorages obtained by the PROMETHEE II method of MCA. No. (column 1 of Table 50) represents the serial number of the location from Table 14; while the last column represents the order, i.e. rank.

Table 50. The list of the best twenty-five nautical anchorages obtained by PROMETHEE II using the multi-criteria method with the rank

No	Name	Island	Rank PROMETHEE II
15	MARINA Uvala Miline - Eastern coast Ostrica mala	CIOVO, DRVENIK, SOLTA AND MAINLAND	1
74	HVAR Uvala V. Zarace	HVAR	2
42	HVAR Uvala Vinogradisce	HVAR	3
28	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	4
41	HVAR Uvala Tarsce	HVAR	5
77	VIS Budikovac	VIS	6
78	VIS Uvala Stoncica	VIS	7
43	HVAR Uvala Vinogradisce	HVAR	8
10	PUCISCA Luka Pucisce	BRAC	9
33	OKRUG GORNJI Zaljev Saldun, Punta Rozac	CIOVO, DRVENIK, SOLTA AND MAINLAND	10

9	PUCISCA Luka Pucisce	BRAC	11
79	VIS Uvala Stoncica - Uvala Vela Cavojnica	VIS	12
40	HVAR Uvala Tarsce	HVAR	13
17	OKRUG GORNJI Uvala Sveta Fumija	CIOVO, DRVENIK, SOLTA AND MAINLAND	14
13	SUTIVAN Uvala Vica	BRAC	15
34	DRVENIK MALI Uvala Vela Rina	CIOVO, DRVENIK, SOLTA AND MAINLAND	16
27	MARINA Luka Vinisce	CIOVO, DRVENIK, SOLTA AND MAINLAND	17
38	HVAR Stipanska uvala	HVAR	18
36	HVAR Luka Soline - Uvala Prevojice	HVAR	19
22	SOLTA Uvala Necujam - Uvala Supetar	CIOVO, DRVENIK, SOLTA AND MAINLAND	20
73	HVAR Uvala Vlaka, Pakleni otoci	HVAR	21
37	HVAR Luka Soline - west	HVAR	22
85	VIS Uvala Ruda	VIS	23
67	JELSA Soline Vrboska	HVAR	24
32	OKRUG GORNJI Uvala Duboka	CIOVO, DRVENIK, SOLTA AND MAINLAND	25

Even though the result, i.e. the order of the best locations of nautical anchorages determined by the AHP, TOPSIS, and AHP-TOPSIS-2N methods is not identical to the order obtained by the PROMETHEE II method, most of the best twenty-five locations obtained by the PROMETHEE II method of MCA coincide with the list of the best obtained by AHP, AHP-TOPSIS-2N methods.

6.4.5. Comparative results of AHP/TOPSIS/AHP-TOPSIS-2N/PROMETHEE II MCA method

Table 51. Comparison of scores and ranks of AHP, TOPSIS, AHP-TOPSIS-2N, PROMETHEE II methods

No1	No	score AHP	Rank AHP	Score TOPIS	Rank TOPSIS	Score AHP-TOPSIS-2N	Rank AHP-TOPSIS-2N	Rank PROMETHEE II
1	15	0.832327588	1	0.724346575	1	0.699889269	1	1
2	74	0.430915609	31	0.532554615	16	0.471952728	23	2
3	42	0.558053342	6	0.61128107	3	0.544088478	4	3
4	28	0.633467001	4	0.539757511	12	0.53225541	5	4
5	41	0.54608824	8	0.597643544	5	0.526133631	7	5
6	77	0.493449871	19	0.551245114	8	0.503981718	12	6
7	78	0.504525244	17	0.545083421	10	0.485869986	15	7
8	43	0.484106499	20	0.538712479	13	0.479135519	17	8
9	10	0.525466097	13	0.501164176	26	0.47225439	22	9
10	33	0.533055974	10	0.538014799	14	0.514254146	8	10
11	9	0.52745379	12	0.509581825	24	0.476875495	19	11
12	79	0.505913008	16	0.550544036	9	0.496976793	13	12
13	40	0.474357365	23	0.51992934	21	0.464924159	25	13
14	17	0.531446832	11	0.52156052	20	0.490374251	14	14
15	13	0.555391086	7	0.532237587	17	0.503992407	11	15
16	34	0.717805187	2	0.621553767	2	0.589832527	2	16
17	27	0.538141018	9	0.494826881	29	0.473317616	21	17
18	38	0.434102576	27	0.556354372	7	0.482751521	16	18
19	36	0.420490885	34	0.541223806	11	0.46495083	24	19
20	22	0.481857819	21	0.482041824	33	0.45786051	27	20
21	73	0.378875697	45	0.433121049	66	0.363217574	69	21
22	37	0.47868848	22	0.587403836	6	0.530797326	6	22
23	85	0.417736615	36	0.482242065	32	0.431495191	37	23
24	67	0.377737423	46	0.438824422	61	0.364661476	68	24
25	32	0.575918613	5	0.531495438	18	0.511230797	9	25
	16	0.516446823	14	0.499930358	27	0.478861082	18	26
	45	0.377158552	47	0.372290955	83	0.38604058	52	27
	23	0.507638996	15	0.533211029	15	0.511113226	10	28
	82	0.291553841	82	0.427279161	72	0.357810113	76	29
	21	0.428515244	32	0.469966194	38	0.437245298	35	30

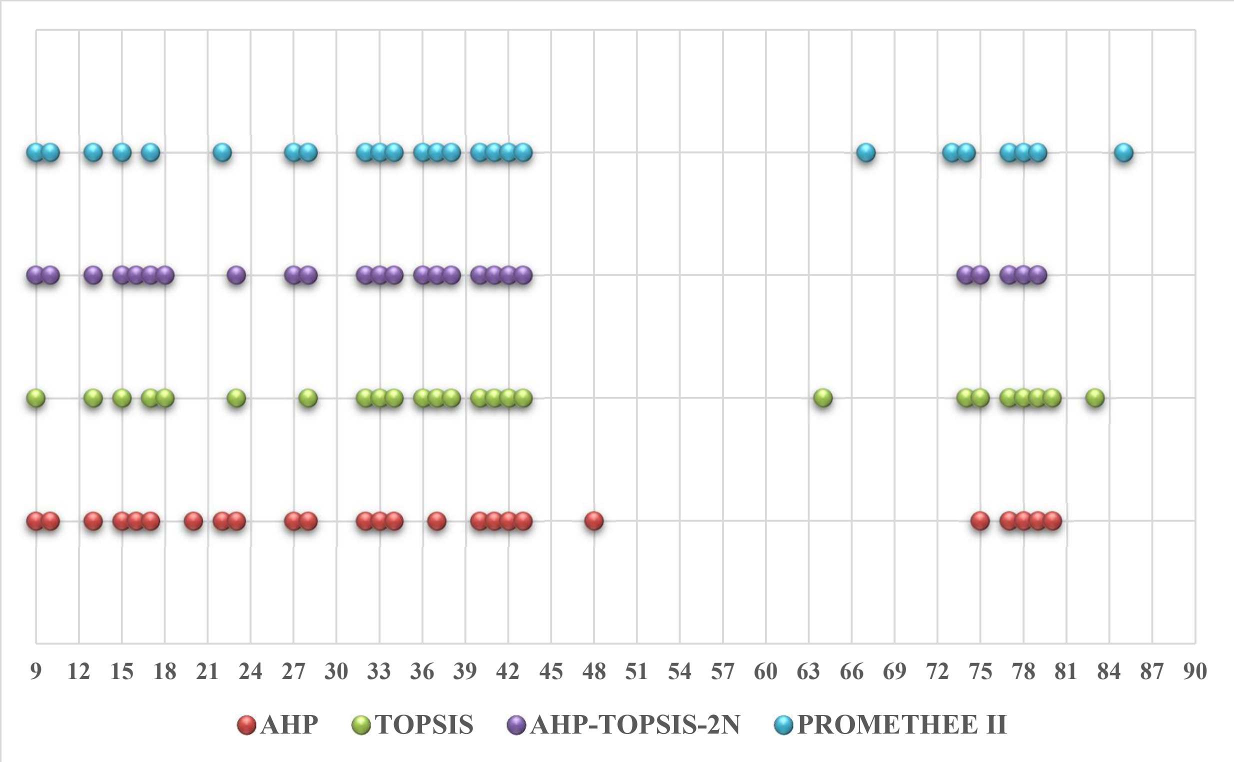
Table 52. Comparative results of all four applied methods of MCDM

AHP	TOPSIS	AHP	AHP-TOPSIS-2N	AHP	PROMETHEE II	TOPSIS	AHP-TOPSIS-2N	TOPSIS	PROMETHEE II	AHP-TOPSIS-2N	PROMETHEE II
15	15	15	15	15	15	15	15	15	15	15	15
34	34	34	34	34	74	34	34	34	74	34	74
75	42	75	75	75	42	42	75	42	42	75	42
28	75	28	42	28	28	75	42	75	28	42	28
32	41	32	28	32	41	41	28	41	41	28	41
42	37	42	37	42	77	37	37	37	77	37	77
13	38	13	41	13	78	38	41	38	78	41	78
41	77	41	33	41	43	77	33	77	43	33	43
27	79	27	32	27	10	79	32	79	10	32	10
33	78	33	23	33	33	78	23	78	33	23	33
17	36	17	13	17	9	36	13	36	9	13	9
9	28	9	77	9	79	28	77	28	79	77	79
10	43	10	79	10	40	43	79	43	40	79	40
16	33	16	17	16	17	33	17	33	17	17	17
23	23	23	78	23	13	23	78	23	13	78	13
79	74	79	38	79	34	74	38	74	34	38	34
78	13	78	43	78	27	13	43	13	27	43	27
48	32	48	16	48	38	32	16	32	38	16	38
77	18	77	9	77	36	18	9	18	36	9	36
43	17	43	18	43	22	17	18	17	22	18	22
22	40	22	27	22	73	40	27	40	73	27	73
37	83	37	10	37	37	83	10	83	37	10	37
40	80	40	74	40	85	80	74	80	85	74	85
80	9	80	36	80	67	9	36	9	67	36	67
20	64	20	40	20	32	64	40	64	32	40	32

The data in Table 52 reveal that the order of the top 25 locations identified by MCA methods, while not identical, is different for at most 6 and at least 3 locations. When comparing results from AHP and TOPSIS, from AHP and PROMETHEE II, and from TOPSIS and PROMETHEE II, the results show that they differ most for six (6) locations.

Graphical interpretation of comparative results is shown in Chart 24.

The *x*-axis shows the serial number of the location, while the y-axis shows whether the location is marked as one of the 25 bests by AHP, TOPSIS, AHP-TOPSIS-2n or PROMETHEE II method.



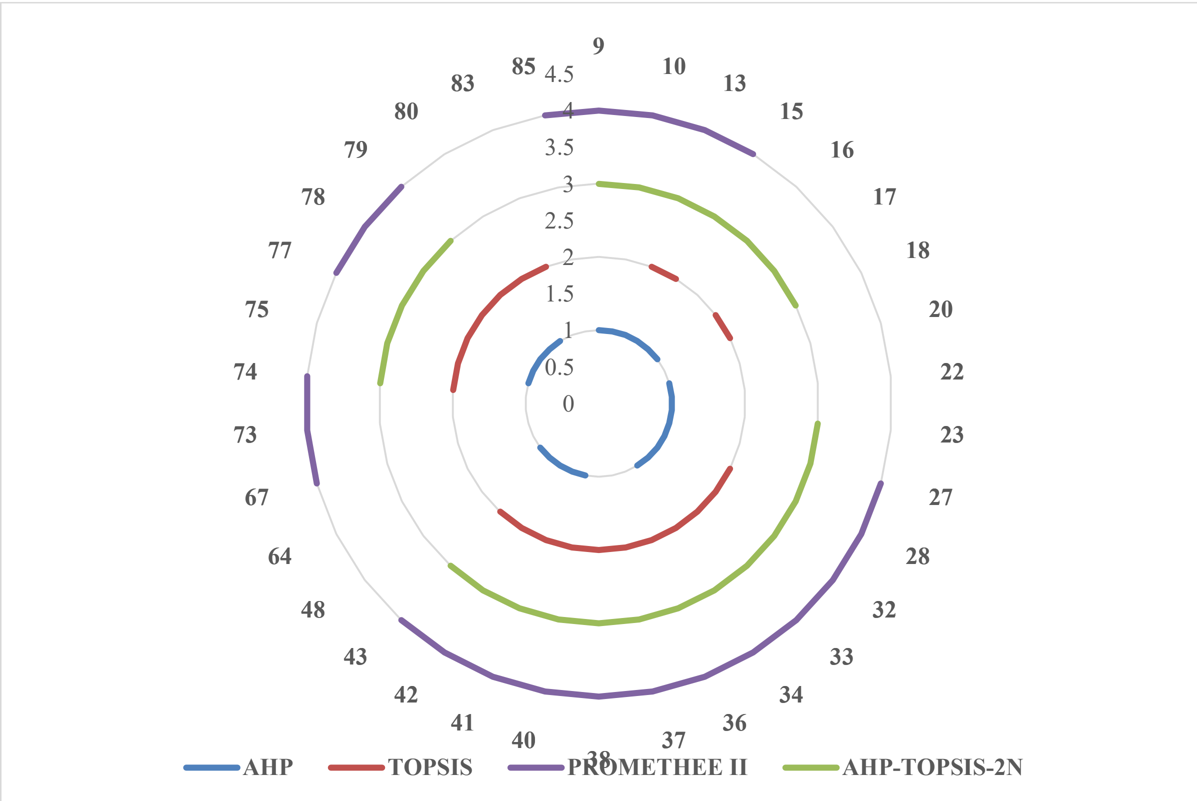


Chart 24. Graphical interpretation of the comparative results

The most similar results were obtained by the TOPSIS and AHP-TOPSIS -2N methods. They differ at 3 locations, while the AHP and AHP-TOPSIS -2N, and AHP-TOPSIS -2N and PROMETHEE II methods differ at 4 locations. The reason for this lies in the different starting points, the different numbers, the relationship between the criteria, and the different calculations of the analysed and considered MCA method.[120]

PROMETHEE II does not agree with the top 25 sites identified by the AHP method, except for six locations. These are the ones marked with ordinal numbers: 74, 38, 36, 73, 85, and 67. These six locations of MCDM PROMETHEE II are among the top 25, while not covered by the AHP method.

PROMETHEE II disagrees with TOPSIS's 25 best locations, also with six locations, namely 10, 24, 22, 73, 85, and 67. These six locations of MCDM PROMETHEE II are among the top 25, but they are not included in TOPSIS 25.

PROMETHEE II disagreed with the results of the AHP-TOPSIS-2N hybrid method only at 4 locations, namely the locations with ordinal numbers 22, 73, 85 and 67. These four locations were included in the list of the 25 best locations of MCDM PROMETHEE II. However, they were not included in the list of the 25 best locations of AHP-TOPSIS -2N.

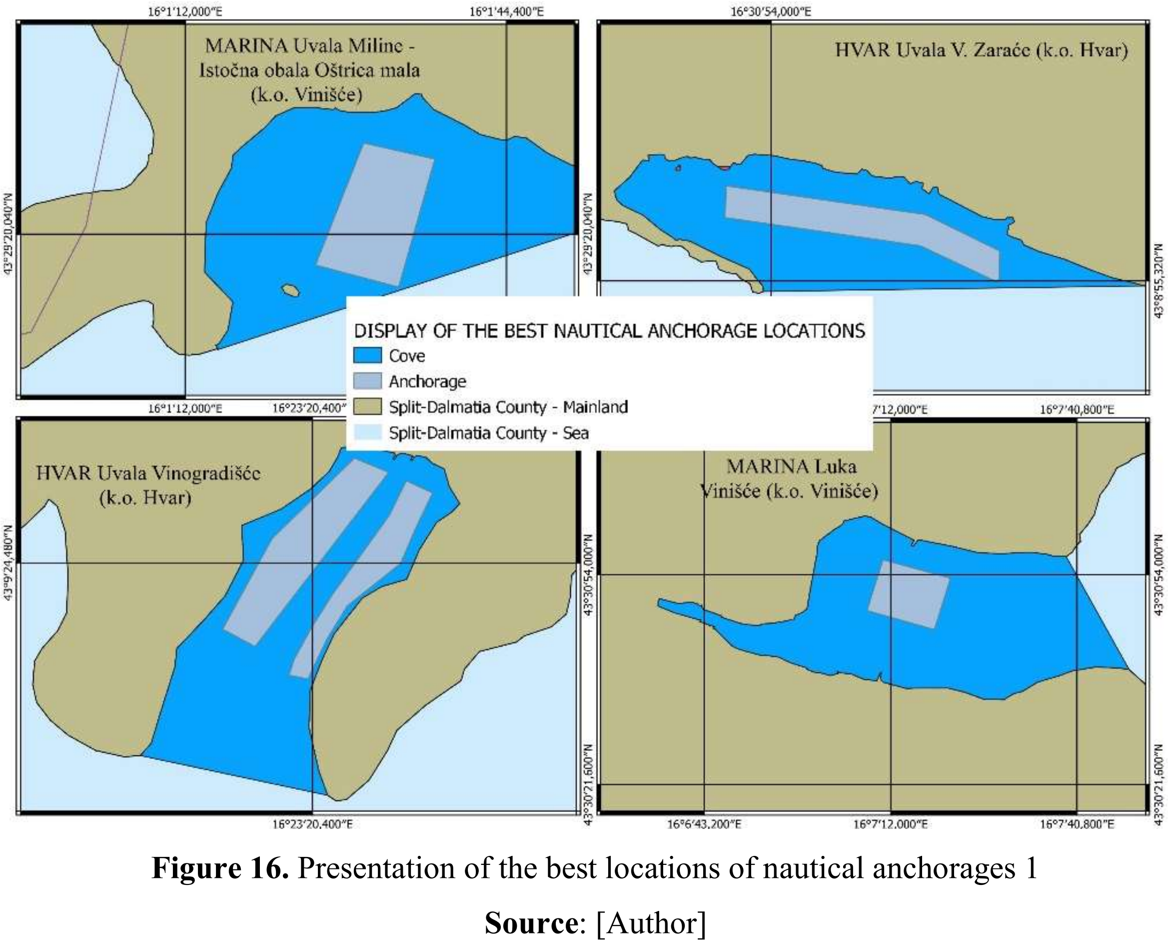


Figure 16. Presentation of the best locations of nautical anchorages 1

Source: [Author]

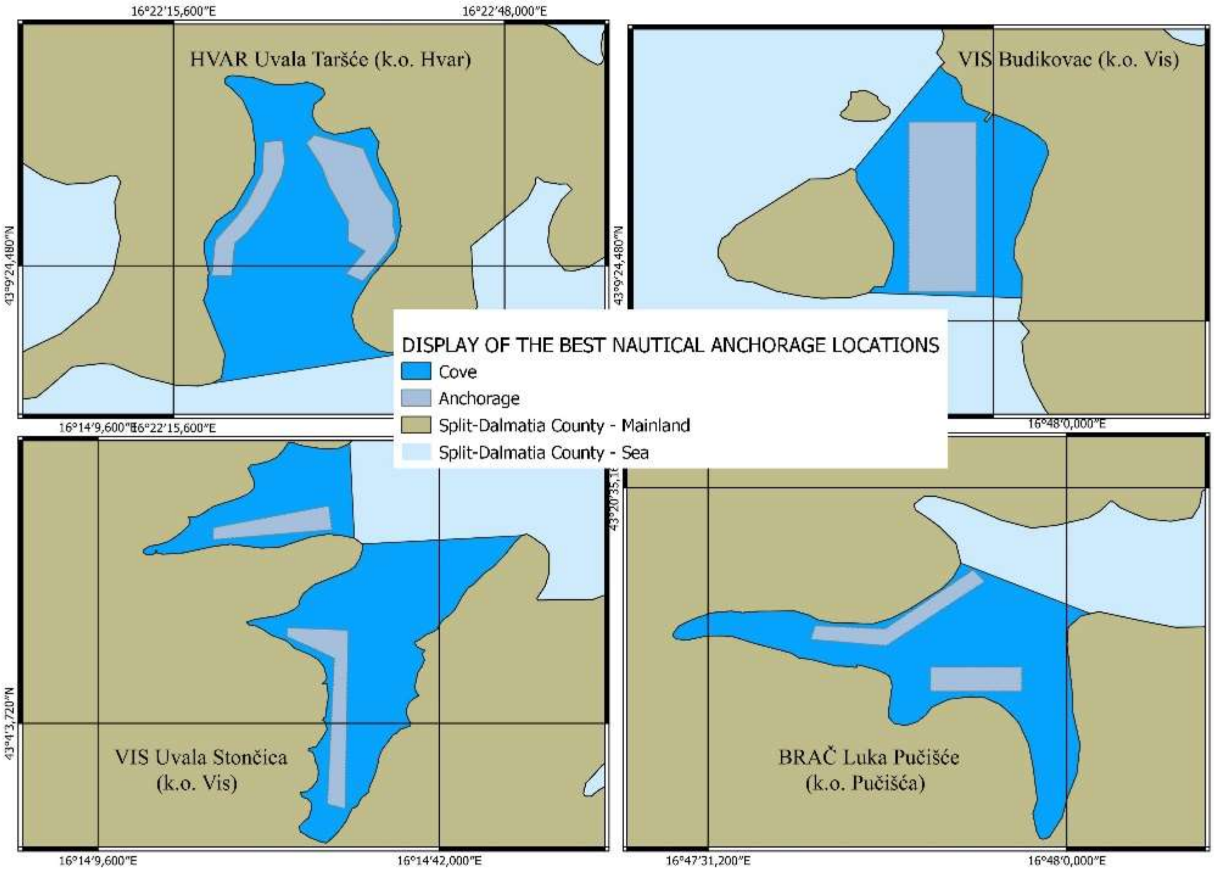


Figure 17. Presentation of the best locations of nautical anchorages 2

Source: [Author]

Figures 16 and 17 show the best locations for anchoring vessels, considering the results of four different methods of MCA. The surface of the bay is denoted by blue, while anchorages within the bay are indicated in light blue. These images provide an insight into the selection of the best anchorages, which are the result of the analyses carried out with respect to different criteria that influence the quality of anchoring, such as protection from weather conditions, the distance of the anchorage from the shore, etc.

Considering the fact that all four applied methods of MCA gave mostly the same or similar results, the study with the proposed methods and the obtained solution represents a strong and effective decision-support tool for the further planning and decision-making process.

With more than ten criteria, it is very difficult - if not almost impossible - to create a consistency matrix where the consistency coefficient is less than 10%, so that the AHP and AHP-TOPSIS-2N methods can be used. Since researchers who want to use the AHP and AHP-TOPSIS-2N methods in the analysis of numerous criteria and alternatives have to transform the data manually, which is very tedious and error-prone work, the use of these methods is not recommended despite their simplicity.

Since the TOPSIS and PROMETHEE II methods have no difficulty in handling many criteria, their mutual relationships, and the number of alternatives, they are suitable for use in all areas where MCDM is required.

For the decision-makers in spatial planning and utilisation in the selection of the best locations for the establishment of nautical anchorages, the solution obtained in this way allows them to be guided by the idea of selecting those locations that best meet the conditions required by sailors, but also the conditions set by the spatial planners, the interested parties concerned for the maritime safety, the future concessionaires, and/or the administration of SDC.

6.5. Validation of results

In order to verify the robustness, reliability, stability and accuracy of the obtained solutions, the internal and external validation of the results obtained with the TOPSIS method is performed. This is to ensure that the method used in the MCA process provides accurate and valid results suitable for decision-making.

Internal validation verifies the stability of the results by checking their consistency. This is done by comparing the obtained results with data that change partially or slightly to observe the changes that occur.

Verifying the method's transparency and traceability is another step in the MCDM validation process. It ensures that all relevant evaluation criteria and participants are included. In any case, it is imperative to perform validation to ensure that the approach provides accurate results that can be used for decision-making.

Internal and external validation are the two main validation methods in the MCDA process. In this dissertation, both the internal and external validation are used by applying the TOPSIS MCDM method.

Consistency of the results and predictive validity represent the two main categories of the internal validation procedure and are used to compare with other approaches and to analyse the stability of the results. The extent to which the results of the method are consistent with what the analysis asserts is called predictive validity.

As a result, the consistency of the outcomes determines how well the procedure can be measured. The predictive method can be applied to the MCDM method by comparing the results of different methods and determining whether the given results are comparable.

Therefore, internal validity is a measure of confidence in a method. It can be applied to the MCDM method by determining whether different methods have produced comparable results and by taking precautions to ensure the accuracy of the current state data.

Internal validation has already been applied to some extent in the presentation and analysis of results, as the results that have been obtained using several MCA methods: AHP, TOPSIS, AHP-TOPSIS -2N, and PROMETHEE II are very similar.
Stability analysis is used to check the consistency and reliability of the results of the MCDM and is therefore extremely useful. It examines how the results change when the parameters of the method or the input data change slightly. Stable results indicate that the method is producing accurate results because they are reliable and consistent. Stability analysis can also show which elements of the method, parameters and values are most sensitive to change.
External validation involves determining how well the methods used can be used in different contexts. This can be achieved by comparing the results with those obtained using alternative techniques, or by analysing the similarities between the results of different studies. Thus, external validation is about confirming that the results of a method can be applied to different data sets or situations.
External validation is used in research because the data to be validated were obtained based on surveys, by applying a different or alternative research technique.
As part of the survey, respondents had the opportunity to graphically represent the location of nautical moorings at the site within a group of 86 sites and to indicate both the shape and size of the area of nautical moorings. To establish the values for the five test locations - fields, their size, and their distance from the coast - useless data had to be sorted out, while the relevant data had to be cleaned and then structured and organised. The information gathered this way was used to determine the fields' surface area, their relationship to the bay's surface area, and their distance from the coast.
For each of the five test locations proposed by the respondents, the input data are identical to the data for the five existing locations from the group of 86 locations, except for: 1. field surface: 2. percent of field surface in the bay; and 3. distance from shore.
The five test sites are labelled: 4PIA, 11PIA, 42PIA, 46PIA, and 74PIA. Table 53 shows the data for the sites used to compare the order of results obtained and the values of the elements that change in the locations labelled with numbers: 4 and 4T; 11 and 11; 42 and 42T; 46 and 46T; and 74 and 74T.

Table 53. Data on five other locations whose values are currently being validated, tested

No	surfaceF	percentage	distance
4PIA	3,278.2	19.19468	5.6
11PIA	16,588.6	27.77998	30.2
42PIA	46,613.6	5.565697	12.6

46PIA	12,947.1	16.5399	29.8
74PIA	14,430.2	26.97902	22.5

Table 54. Information about the sites with which the validated results are compared

No	surfaceF	percentage	distance
4	3,416.15	28.94899	12.4
11	15,056.05	15.01185	7.4
42	33,300.56	19.2737	15.6
46	11,217.76	4.822289	7.4
74	16,066.28	21.37095	23.2

Table 55. Summary of the data on the validated locations and the data on the locations of the nautical anchorages with which the obtained results are compared

No.	**4**	**4PIA**	**11**	**11PIA**	**42**	**42PIA**	**46**	**46PIA**	**74**	**74PIA**
surfaceF	**34,16.15**	**3,278.2**	**15,056.05**	**16,588.6**	**33,300.56**	**46,613.6**	**11,217.76**	**12,947.1**	**16,066.28**	**14,430.2**
surfaceB	11,800.584	11,800.58	100,294.433	100,294.4	172,777.2	172,777.2	232,623.143	232,623.1	75,178.13	75,178.13
percentage	**28.948991**	**27.77998**	**15.01185016**	**16.5399**	**19.2737**	**26.97902**	**4.82228898**	**5.565697**	**21.37095**	**19.19468**
protection	9	9	9	9	1	1	1	1	5	5
distance	**12.4**	**5.6**	**7.4**	**30.2**	**15.6**	**12.6**	**7.4**	**29.8**	**23.2**	**22.5**
numberF	1	1	2	2	2	2	4	4	1	1
traffic	1	1	1	1	1	1	5	5	1	1
anchorage	1	1	1	1	1	1	1	1	1	1
cables	1	1	1	1	1	1	1	1	1	1

danger	3	3	3	3	3	3	5	5	3	3
depth	5	5	5	5	5	5	5	5	5	5
tide	1	1	1	1	1	1	5	5	1	1
proximityP	1	1	1	1	1	1	1	1	1	1
existingB	1	1	1	1	1	1	1	1	1	1
environment	5	5	1	1	5	5	5	5	5	5
harmfulness	5	5	1	1	5	5	5	5	5	5
site	1	1	1	1	1	1	1	1	1	1

Table 56. Validated dataset

No.	4	4T	11	11T	42	42T	46	46T	74	74T
surface F	3,416.2	3,278.2	15,056.1	16,588.6	33,300.6	46,613.6	11,217.8	12,947.1	16,066.3	14,430.2
percentage	29.0	27.8	15.0	16.5	19.3	27.0	4.8	5.6	21.4	19.2
distance	12.4	5.6	7.4	30.2	15.6	12.6	7.4	29.8	23.2	22.5

In order to validate the methods used, the following section of the dissertation documents the method used to validate the obtained results.

Considering that it would be totally impractical and highly unnecessary to validate the results with all four MCDM methods used in the empirical research, the data are validated/tested with the TOPSIS method and include a dataset of 91 anchorage locations, 86 original and 5 new. The validation results showing possible changes in the sequence were obtained using the TOPSIS method of MCA and are presented in Table 57.

Table 57. Changing the order of locations used for validation

Rank	Score	No
2 ↑	**0.677367199**	**42PIA**
4	**0.608256708**	**42**
18	**0.527340126**	**74**
23 ↓	**0.512747238**	**74PIA**
34	0.479203486	**4**
40 ↓	0.471523883	**4PIA**
47 ↑	**0.456666886**	**11PIA**
61	**0.438131969**	**11**

89 ↑	**0.359936881**	**46PIA**
90	**0.347016121**	**46**

The validation results indicate very small sequence changes. The location marked with the number 4PIA, which the survey respondents proposed to have a surface of 3,278.2 m^2, with a share of 27.78% in the surface of the bay, a surface of 11,800,584 m^2 and a distance from the coast of 5.6 m, instead of the area of 3,416.15 m^2 that has location 4, with a share of 28.9% in the surface of the bay and distance from the coast 12.4 m that location 4 had, occupies the 40th position (row 7 of Table 57) instead of the 34th (row 6 of Table 57) that was occupied by the location marked with ordinal number 4. Therefore, given that location 4 occupied 34th place, and the location labelled 4PIA ranks 40th the list, no significant change has occurred. However, neither the location 4PIA nor the location marked with serial number 4 belong to the group of the 25 best locations for nautical anchorages. The same happens with the locations marked with the serial numbers 46 and 46PIA, as well as the locations marked with the serial numbers 11 and 11PIA.

The locations marked with serial numbers 42 and 42PIA are in the 4th and 2nd positions, respectively, confirming that location 42 (as well as 42PIA) is an excellent choice for the location of a nautical anchorage, as is location 74 (or 74PIA), because they are both on the list of the top 25 nautical anchorage locations, with the location marked 42T now taking the 2nd position and the location marked 42 the 4th.

However, if it is needed to decide between locations denoted by 74 and 74T, it would be better to use the data determined by those comprised in location denoted by 74.

In order to confirm the stability and consistency of the results, the data related to the location number 15 (MARINA Uvala Miline – Eastern coast Oštrica mala (Vinišće)) are also validated. In all applied methods of MCA, this location is at the very peak of the best locations and occupies the 1st place, the nautical anchorage field marked with number 15.

To test the obtained results, the data on this location are used for different values of the protection of locations 15 where this value is 1-protected bay; 15A with protection value 5-partially protected and 15B - 9-protected.

Regardless of the value used for this parameter of protection of the bay, it will remain on the list of the 25 best locations for nautical anchorages.

For example, if the protection value five (5) is used for the site 15A, the position - rank will change, it will fall on the 2nd position. If the value nine (9) is used for the protection parameter, the site 15B will be in 8th position. (Table 58)

Table 58. Changing the order of the locations used for validation

Position	Score	No.	Protection
1	0.716785734	15	1
2 ↓	0.662431165	15A	5
8 ↓	0.584089127	15B	9

The obtained results show that it is possible to select the best locations for nautical moorings in SDC area by applying the MCA methods.

From the application of the internal and external validation of the obtained results, it can be concluded that the obtained results are very stable and consistent, and that the order of the best 25 sites would not change due to insignificant/small changes in the input data.

When determining the best (optimal) locations for nautical moorings, several factors and criteria were considered, the most important of which are: navigation safety, hydrometeorological, spatial, economic and ecological aspects. The results indicate and confirm that several different MCA methods gave very similar results.

In addition, the results also confirm that by using multiple MCA methods it is possible to rank moorings within the same location, not just locations (bays, coves or other sheltered areas). The obtained results were confirmed by expert analysis as well as the results of the field ranking, all in accordance with the values of the weighting coefficients to which the values were assigned in such a way that priority was given to those elements that both users and future concessionaires highlighted as the most important.

All of the above indicates that this approach significantly differs from the previous scientific approaches and contributions of the researchers dealing with this issue.

Therefore, by applying a unique expert analysis, by establishing systematic relationships between criteria, by classifying fields and not only areas, and by comparing multiple MCA methods, the obtained results – verified through the validation process – confirm credibility, reliability, robustness and applicability in other and similar areas of spatial planning and applications of the MCA.

7. FURTHER RESEARCH

The MCDM methods and their basic structure can represent an evolving body of knowledge in the field of MCDA. In this sense, one can think of several extensions of the research conducted in this dissertation.

The first is the extension of MCDM methods by including a larger dataset on the number of possible locations and the number of criteria in the case study in the selection of optimal locations for nautical anchorages, not only for the SDC area, but in the whole Adriatic region and beyond, by exploring locations for nautical anchorages and by identifying trends in the application of MCA methods in the fields of maritime safety, nautical tourism, spatial planning etc.

This means that the Split-Dalmatia County database of anchorages has been significantly enriched and expanded by this research and can serve as a new source of input data for new case studies and as a useful tool for selecting optimal future locations for nautical anchorages in these areas.

Further expansion could be dedicated to the application of methods to support multiple decision-making that originated in the field of operational research, where final decisions are made not by individuals but by groups of people such as committees, boards, etc.

Considering the generality of the procedures used in the MCA methods, one can imagine their adaptation to the methods of analysis of conscious decisions and their consideration from the point of view of only certain interest groups, for example, in the evaluation of the efficiency and profitability of the use of the concession areas of nautical anchorages of future concessionaires.

When using the R language and its packages and functions, user interaction is a key factor in the development of the MCDM process. This approach allows users to change input data, observe output results, and evaluate how changing input data affects final decisions. Therefore, the use of the R language along with user interaction can be very useful in the development of MCDM processes, as it allows decision makers to better understand and make decisions based on complex data.

The selection of different MCDM methods might influence the future use of some of the methods used here or suggest others, since a wide range of methods is available, especially in the R package. This may lead to a significant challenge for analysts and experts in the fields of maritime safety, navigation, spatial planning, future concessionaires, etc., who may be asked to suggest and choose one method for a project over another one. This may require them to increase or decrease their own or subjective evaluations and values of individual elements, criteria, and their weighting values (i.e. to reduce or increase them) in order to meet some other equally important selection criteria.

The final selection of the processed MCDM methods and analyses may be influenced by some qualitative characteristics of the methods, such as easier applicability, use in certain domains, availability of the software implementing them, etc. Of course, the application of a certain MCDM method instead of another and the selection of a certain criterion and its weighting values are exclusively subjective elements, making the final result less dependent on real, i.e. objective values.

The MCA methods were used for the case study to select the best locations for nautical anchorages in the SDC area. They are meant to assist analysts and interested parties, future concession users, spatial planners, scientists, entrepreneurs, and others in dealing with the problem of MCDM. This dissertation explains all methods in detail to help decision-makers understand the rationale for choosing a particular method, data and criteria, and to encourage them to choose methods, data and criteria that meet their decision-making needs and satisfy any constraints that characterise the decision-making situation, especially in the fields of maritime security, maritime economics, spatial planning, and nautical tourism. Through the joint work of experts from multiple fields, the results can be expanded, and the repository of methods enriched with methods that will be tested in future case studies, with the inclusion of additional decision support functions based on both web and other software.

The result can be a sustainable contribution to the relevant and transparent application of MCDM methods to solve groups of problems in various fields, not only in the field of maritime safety, spatial planning, shipping, nautical tourism, and maritime economy.

8. CONCLUSION

The purpose and objective of this doctoral dissertation were to demonstrate the applicability of MCDM methods in the process of site optimisation of nautical anchorages in Split-Dalmatia County in Croatia.

The MCDM methods included the application of AHP, TOPSIS, AHP-TOPSIS-2N, and PROMETHEE II, based on which the 25 best from the group of 86 possible variants, . locations, were selected in the selection process.

The evaluation and assignment of weighting values of the criteria were based on the ratings of the most important elements of nautical anchorages given by the respondents in the first phase. The data were collected by means of a questionnaire that was prepared, distributed, and completed by 74 users/sailors between November 2022 and mid-January 2023.

The respondents completed the questionnaire featuring five groups of elements defining the characteristics of nautical anchorages, with a total of seventeen sub-elements referring to: 1. three elements related to the safety of navigation of nautical anchorages: a) the presence of underwater facilities; b) potential hazards during navigation; and c) manoeuvring space; 2. three hydrometeorological elements related to a) protection of the area during anchoring; b) presence of sea currents; and c) tides; 3. three spatial elements of nautical anchorages related to a) distance from shore and water depth; b) turning radius required by the vessel; and c) occupied space; 4. five economic elements of nautical anchorages related to a) proximity to the port area; b) proximity to public anchorages; c) access to land; d) state of transportation and other infrastructure; and e) profitability; and 5. four environmental elements of nautical anchorages regarding the a) impact on nature; b) seabed disturbance; c) pollution and littering; and d) importance and condition of local heritage.

Using the questionnaire based on the scores of the previously listed items, the relationships between the criteria or objectives and their weighting values were determined. This was done depending on the MCA method applied to each of the 86 possible variants. When the AHP and AHP-TOPSIS-2N methods were used, 10 of the 17 known criteria were analysed, while TOPSIS and PROMETHEE II considered all 17 criteria. The optimisation problem was contextualised by considering the objective function for site selection optimisation based on the criteria: field surface; surface of the bay; percentage of field surface to the surface of the bay; protection of the bay; distance from shore; number of anchorages in the bay; presence of vessel traffic; presence of an official anchorage; presence of underwater cables and pipelines; risk of collision; depth; tide level and presence of sea currents; proximity to public ports; proximity to the existing moorings; environmental features (Natura 2000 ecological network); disturbance of the seabed by vessel anchoring; and archaeological sites.

Different initial settings specific to each of the methods were applied, and the relationship between the criteria, the objective function of each criterion, and their weighting values were determined for each of the eighty-six possible locations for nautical moorings in the Split-Dalmatia County area. Application of four MCA methods resulted in the selection of twenty-five best locations.

The application of the MCA methods relies on the support provided by the R language. It also relies on the features of this package available for most MCA methods.

When applying multiple MCDM methods with different initial settings depending on the determination procedure and the conditions specified for each of the four methods, the solutions for selecting the twenty-five best of eighty-six possible variants for nautical moorings are almost identical.

When the multi-criteria AHP method was used, the consistency ratio between criteria was 9.449231%, and when the hybrid AHP-TOPSIS-2N method was used, it was 9.6680424%. Both are considered as acceptable since they are less than 10% and reflect an accurate evaluation of the criteria and their relationships.

The same criteria targets and weighting values are applied in the MCA methods TOPSIS and PROMETHEE II, while the original consistency matrix and criteria, as well as the relationship between criteria are used in the AHP and AHP-TOPSIS-2N methods.

The application of the MCA methods and the results obtained showed that all four methods produced very similar solutions, differing in at most six (6) and at least three (3) locations. This confirmed their effectiveness in selecting the best locations for nautical moorings in SDC. Respondents and proposals for the shape and size of nautical moorings were used to validate the results. This confirmed that the results obtained using the MCA methods were stable and consistent. They were not significantly different from the suggestions for the location of nautical moorings, which were based on direct users' suggestions.

Future improvements could include the addition of various criteria not previously considered, such as water depth, noise level, environmental conditions, etc. Consideration could also be given to incorporating experts' and residents' opinions into the process of selecting anchorages. This would provide additional perspectives and improve decision-making. Finally, it should be taken into account that marine conditions may change over time, which may affect the quality of the chosen anchorage location. Therefore, conditions at the selected locations should be reviewed periodically and the decisions reconsidered as circumstances change. However, for future applications to problems of similar nature, which involve spatial determination or selection of the most appropriate sites using MCDM that have more than ten criteria, the use of TOPSIS and PROMETHEE II methods is recommended due to their simplicity and efficiency.

Through the application of validation, the robustness, reliability, stability and accuracy of the solutions obtained were verified, all with the aim of ensuring efficient decision-making for the selecting the best locations of nautical anchorages using the MCA method. The conclusion is that the basic hypothesis formulated at the beginning has been confirmed. This means that it is possible to use the MCA method to determine the most suitable nautical anchorage or to assess anchorages in general. In determining the most suitable anchorages, several factors and criteria have to be taken into account, the most important of which are safety of navigation, hydrometeorological, spatial, economic and environmental aspects. Both the views of seafarers and those who make the final decisions and/or propose solutions should be taken into account.

Although there are many other methods of MCDM in determining the locations of nautical anchorages, the solutions and methods used in this work are simple, useful, reliable, realistic and very exemplary in Croatia, especially because there are a large number of inexperienced charterers in Croatia. Thus, this work contributes to both social and technical aspects.

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10. LIST OF CHARTS

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12. LIST OF FIGURES

13. BIOGRAPHY OF THE AUTHOR WITH A LIST OF PUBLISHED PAPERS

Danijel Pušić was born in Split on June 16, 1970. He completed primary education and secondary Maritime School in Split. After finishing high school, he completed an apprenticeship (cadetship) on an ocean-going vessel as a deck trainee (cadet). Upon completion of the one-year apprenticeship, he passed the exam to become a merchant navy ship officer. From 1991 to 1993, he served as a Third Officer on a foreign company vessel (Tanker Pacific Singapore). From 1993 to 1995, he worked as the captain of a fishing boat. From 1995 to 1996, he served as a Third and Second Officer on a foreign company vessel (Lundqvist Rederierna Finland). From 1997 to 2018, he was employed at the Croatian Hydrographic Institute in Split.

In the academic year 2006/2007, he graduated from the Higher Maritime School in Split, specialising in Nautical Science with the thesis "Navigation Guidance and Monitoring System in the Adriatic Sea."

In the academic year 2008/2009, he graduated from the Faculty of Maritime Studies in Split, specialising in Nautical Science with the thesis "Application Level of Electronic Charting and Information Systems."

In the academic year 2009/2010, he enrolled in the Interuniversity Postgraduate Doctoral Study Program "Maritime Affairs - Nautical Sciences" at the Faculty of Maritime Studies in Rijeka. Since December 2010, he was engaged as an assistant at the Department of Nautical Science at the University of Split - Faculty of Maritime Studies, where he conducted exercises in Terrestrial and Celestial Navigation and served as a lecturer in ECDIS training. In September 2012 he became a lecturer responsible for the courses Ship Knowledge and Navigation Elements. In April 2012, he passed the professional examination and obtained the status of a certified engineer. He is a member of the Croatian Chamber of Traffic Engineers - Maritime Traffic Division and Inland Waterways Traffic Engineers.

He is fluent in English, proficient in Italian and German.

During his time at the Hydrographic Institute, he participated in the production of Sailing Directions I, Sailing Directions for Small Craft Parts I and II, List of Lights and Fog Signals, Radio Services for Mariners, Nautical Tables, and the General Chart. He actively participated in the production of nautical charts and conducted numerous fieldwork activities related to hydrographic surveying.

On 14 February 2018 he became a Senior Lecturer at the Faculty of Maritime Studies in Split. As a Senior Lecturer he performs various duties, including developing curriculum, delivering lectures, conducting examinations, providing academic support to students, and participating in research projects. His work contributes to the quality of the educational process, and he strives to motivate students to excel and achieve their academic goals.

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Zvonko ; Jelić-Mrčelić, Gorana (ed.); Croatian Hydrographic Institute, Split, 2011, pp. 155-165. (https://www.bib.irb.hr/518085)

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1. Vukić, Luka; Lušić, Zvonimir; Peronja, Ivan; **Pušić, Danijel**;
Overview of the factors affecting compliance and safety of pilot transfer arrangements (PTA). // Naše More 2021 Conference Proceedings
Dubrovnik, Croatia, 2021. pp. 360-376. (https://www.bib.irb.hr/1144177)

2. Vojković, Lea; Bićanić, Zlatimir; **Pušić, Danijel**;
Turističko i pomorsko-prometno vrednovanje otoka Visa sa stajališta održivog razvoja. //
Proceedings of the International University of Travnik Conference, Travnik - Vlašić, Bosnia and Herzegovina / Ramić, Larisa (ed.), 2013. pp. 227-236.

14. APPENDIX A

Appendix A contains a code listing for each of the methods in the R programming language. The AHP and AHP-TOPSIS-2N methods were applied to the same input data with 10 selected criteria, while TOPSIS and PROMETHEE II used all 17 available criteria.

```
#################################################
# AHP
rm(list=ls())
# instalating library and packages
install.packages("readxl")
install.packages('writexl')
install.packages('ahptopsis2n')
if(!require('topsis')) {
 install.packages('topsis')
 library('topsis')
}
install.packages("xlsx")
library(openxlsx)
library(writexl)
library(xlsx)
library(ahptopsis2n)
library("readxl")
setwd("C:\\DP")
# input of data
criteria<-read_excel("C:/DP/criteriaahp.xlsx")
RI<-read_excel("C:/DP/RI.xlsx")
RI<-as.matrix(RI)
b <- as.matrix(criteria)
criteria
n<-nrow(criteria)
m<-ncol(criteria)
a <- matrix(0, ncol = m, nrow = m)
suma<-rep(0, m)
# Generating part of matrix
for (i in 1:m) {
```

```
            for (j in 1:m){
if (i>j) {
            print(i)
            print(j)
            a[i,j]=1/b[j,i]
            print(a[i,j])
}
            else {
            a[i,j]<-b[i,j]
            print(a[i,j]) }
}}
# suma of rows
for (j in 1:m) {
s<-0
for (i in 1:m) {
s<-s+a[i,j]
}
suma[j]<-s}
# each element of matrix we divide with sum of rows
# so we have normalise matrix
at<-t(a)
norm<-t(at/suma)
norm

# Weight
weight<-rowMeans(norm)
weight
# Calculating Lamda, CI and CR
prod<-weight*suma
lamda<-sum(prod)
CI<-(lamda-m)/(m-1)
CR<-CI/RI[m]
if (CR<0.10) {
print("Excelent contingency")
print("You have good criteria")
} else
{ print("NOT CONTINGENCY ")}
```

```
print(weight)
ulazni<-read.table("C:/DP/polja-new.txt", header = TRUE, sep='\t')
ulazni1<-as.data.frame(ulazni)
ulazni1
summary(ulazni1)
m<-nrow(ulazni1)
n<-ncol(ulazni1)
kolone<-c(5, 6, 7, 8, 9, 10, 16, 19, 20, 21)

# ULAZNI PODACI ZA AHP
data <- data.matrix(ulazni1[,kolone])
data
vektormax<-apply(data,2,max)
vektormax
vektormin<-apply(data,2,min)
vektormin
normdata<-as.matrix(data)
data
nn<-10
maxmin<-c(1, 1, 1, 0, 1, 0, 0, 0, 0, 0)
        for (i in 1:m)
        {
        for (j in 1:nn)
        {
                if (maxmin[j]== 1)
                {
                print(i)
                normdata[i,j]<- data[i,j]/vektormax[j]
}
        else
        {
        normdata[i,j]<- vektormin[j]/data[i,j]
        print("mini")
        print(i)
        }
        }
}
data
```

```
normdata
ss<-array(c(0),86)

for (i in 1:m)
          {
          as<-0
          print(i)
                    for (j in 1:nn)
                    {
                    as<-as+normdata[i,j]*weight[j]
                    print(j)
                    print("j")
                    }
                    ss[i]<-as
          }
          ss

rank<-ss
rank
ranking<-c(rank(-rank))
dataout<-cbind(ulazni1,rank, ranking)
# saving output data
write.table(dataout,'C:\\DP\\resultAHP.xls', row.names=FALSE, sep='\t')
coefAHP<-cbind(lamda,CI,CR)
write.table(coefAHP,'C:\\DP\\coefAHP.xls', row.names=FALSE, sep='\t')

#################################################
# TOPSIS
rm(list=ls())
install.packages("xlsx")
install.packages("topsis")
install.packages('writexl')
install.packages('ahptopsis2n')
if(!require('topsis')) {
 install.packages('topsis')
 library('topsis')
}
library(writexl)
```

```
library(ahptopsis2n)
library(openxlsx)
library(xlsx)
library("readxl")
setwd("C:\\DP")
ulazni<-read.table("C:/DP/polja-new.txt", header = TRUE, sep='\t')
ulazni1<-as.data.frame(ulazni)
ulazni1
summary(ulazni1)
bk<-ncol(ulazni1)
bk
m<-nrow(ulazni1)
n<-ncol(ulazni1)
data <- data.matrix(ulazni1[,5:bk])
data
weight <- c(5, 4, 9, 13, 3.5, 1,1,1,1,1,1,9,1,1,2,2,1)
weight
# + ako je kriterijum max, a - ako je kriterijum min
# 1 povrsinapolja, 2 povrsinauvale, 3 procenat, 4 otvorenost (9-otvorena, 5-djelimicno, 1-zatvorena),
5 udaljenost, 6 broj polja, 7 promet, 8 sidriste, 9 podvodni, 10 sudar, 11 dubina, 12 plima, 13
blizinaL, 14 postojeciV, 15 ekoloski, 16 stetnost, 17 nalaziste
maxmin <- c("+", "+", "+","-","+","-","-","-","-","-","+","-","-","-","-","-","-")
maxmin
rezultat<-topsis(data, weight, maxmin)
rezultat<<-rezultat[2:3]
all<-cbind(ulazni1,rezultat)
write.table(all,'C:\\DP\\resultTOPSIS.xls', row.names=FALSE, sep='\t')

##################################################
# AHP-TOPSIS-2N
rm(list=ls())
install.packages('writexl')
install.packages('ahptopsis2n')
install.packages("xlsx")
install.packages("topsis")
library(openxlsx)
library(xlsx)
library("readxl")
```

```
library(ahptopsis2n)
library(writexl)
library(ahptopsis2n)
if(!require('topsis')) {
 install.packages('topsis')
 library('topsis')
}
setwd("C:\\DP")
ulazni<-read.table("C:/DP/polja-new.txt", header = TRUE, sep='\t')
ulazni1<-as.data.frame(ulazni)
ulazni1
summary(ulazni1)
bk<-ncol(ulazni1)
bk
m<-nrow(ulazni1)
n<-ncol(ulazni1)

kolone<-c(5, 6, 7, 8, 9, 10, 16, 19, 20, 21)
data <- data.matrix(ulazni1[,kolone])
data
# define the decision matrix
decision<-data
rownames(decision)<- c(1:nrow(data))
#define criteria matrix with pairwise comparison
criteria<-matrix(c(1, 1, 1, 1, 2, 6, 1/2, 2, 2, 5,
1, 1, 1, 1, 1, 5, 1/2, 2, 2, 4,
1, 1, 1, 4, 2, 7, 5, 3, 3, 4,
1, 1, 1/4, 1, 1, 7, 2, 5, 5, 5,
1/2, 1, 1/2, 1, 1, 4, 3, 2, 2, 3,
1/6, 1/5, 1/7, 1/7, 1/4, 1, 1/9, 1/2, 1/2, 1,
2, 2, 1/5, 1/2, 1/3, 9, 1, 4, 4, 9,
1/2, 1/2, 1/3, 1/5, 1/2, 2, 1/4, 1, 1, 2,
1/2, 1/2, 1/3, 1/5, 1/2, 2, 1/4, 1, 1, 3,
1/5, 1/4, 1/4, 1/5, 1/3, 1, 1/9, 1/2, 1/3, 1),
                    ncol=10, byrow=TRUE)
# define each criterion objective
minmax<-c("max","max","max","min","max","min", "min","min","min","min")
# associate the objects to the function arguments and run the function
```

```
result2<-ahptopsis2n(decision=decision[,1:10], criteria=criteria[1:10,1:10], minmax=minmax[1:10])
result2
all<-cbind(ulazni1,result2[[2]], result2[[3]])
cr<-result2[1]
write.table(all,'C:\\DP\\resultAHPTOPSIS2N.xls', row.names=FALSE, sep='\t')
write.table(cr,'C:\\DP\\crAHPTOPSIS2N.xls', row.names=FALSE, sep='\t')


##################################################
# PROMETHEE II
rm(list=ls())
install.packages("ggplot2")
install.packages("xlsx")
install.packages('ahptopsis2n')
install.packages('writexl')
library("ggplot2")
library("readxl")
library(ahptopsis2n)
library(openxlsx)
library(writexl)
library(xlsx)
library(ahptopsis2n)
if(!require('topsis')) {
 install.packages('topsis')
 library('topsis')
}
if(!require('MCDA')) {
 install.packages('MCDA')
 library('MCDA')}
if(!require('promethee123')) {
 install.packages(' promethee123')
 library('promethee123')
}
# input of data
setwd("C:\\DP")
ulazni<-read.table("C:/DP/polja-new.txt", header = TRUE, sep='\t')
ulazni1<-as.data.frame(ulazni)
ulazni1
```

```
summary(ulazni1)
bk<-ncol(ulazni1)
bk
m<-nrow(ulazni1)
n<-ncol(ulazni1)
data <- data.matrix(ulazni1[,5:bk])
data
# define the decision matrix
decision<-data
alternatives <- c(1:m)
alternatives
criteria <- colnames(data)
criteria
performanceTable <-data
performanceTable
rownames(performanceTable)<- c(1:nrow(data))
colnames(performanceTable) <- colnames(data)
# The preference functions
preferenceFunction<-c("Gaussian", "Level", "V-shape-Indiff", "Level", "Level",
"Level","Level","Level","Level","Level","Level","Level","Level","Level","Level","Level","Level")
preferenceFunction
#Preference threshold
preferenceThreshold<-c(50,1000,3,1,0,0,0,0,0,0,0,0,0,0,0,0,0)
names(preferenceThreshold)<-colnames(performanceTable)
preferenceThreshold
#Indifference threshold
indifferenceThreshold<-c(3,1000,3,1,0,0,0,0,0,0,0,0,0,0,0,0,0)
names(indifferenceThreshold)<-colnames(performanceTable)
indifferenceThreshold
#Parameter of the Gaussian preference function
gaussParameter<-c(4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0)
names(gaussParameter)<-colnames(performanceTable)
gaussParameter
#weights
# 1 povrsinapolja, 2 povrsinauvale, 3 procenat, 4 otvorenost (9-otvorena, 5-djelimicno, 1-zatvorena),
5 udaljenost, 6 broj polja, 7 promet, 8 sidriste, 9 podvodni, 10 sudar, 11 dubina, 12 plima, 13
blizinaL, 14 postojeciV, 15 ekoloski, 16 stetnost, 17 nalaziste
criteriaWeights <- c(5, 4, 9, 13, 3.5, 1, 1, 1, 1, 1, 1, 9, 1, 1, 2, 2, 1)
```

```
criteriaWeights
names(criteriaWeights)<-colnames(performanceTable)
# criteria to minimize or maximize
criteriaMinMax<-c("max","max","max","min","max","min","min", "min", "min", "min", "max",
"min", "min", "min", "min", "min", "min" )
names(criteriaMinMax)<-colnames(performanceTable)
criteriaMinMax
rezultat<-as.vector(PROMETHEEII(performanceTable, preferenceFunction, preferenceThreshold,
indifferenceThreshold, gaussParameter, criteriaWeights,      criteriaMinMax))
rezultat
r<-unlist(rezultat)
r<-as.numeric(c(r))
rezultat<-cbind(rezultat,c(1:86))
write.table(rezultat,'C:\\DP\\promethee2.xls', row.names=FALSE, sep='\t')
```

15. APPENDIX B

Appendix B presents a presentation of the survey form.

Nautical anchorage survey

This survey is conducted for the scientific research on the topic "DETERMINING NAUTICAL ANCHORAGE LOCATIONS USING MULTICRITERIA ANALYSIS".
The goal is to determine the optimal location for nautical anchorages for which, by applying multi-criteria analysis, conceptual frameworks for the optimal anchorage selection will be offered. Research and analysis would provide a framework for determining the anchorage area within a particular marine area, most often natural shelters. The optimal solution means the one that is sufficiently safe from the effects of weather conditions, that does not interfere with the surrounding maritime traffic, and that minimally affects the environment.
The purpose of this survey is to obtain an assessment of the optimal values of the criteria parameters and their weight.

In order for the obtained data to be acceptable and applicable, I would appreciate your involvement and expert opinion, which is of great importance for the research.

If you have any further questions please don't hesitate to contact me.

Respectfully,

Danijel Pušić MBsc
Senior Lecturer
University of Split - Faculty of Maritime Studies
danijel.pusic@pfst.hr
+385 21 619 482

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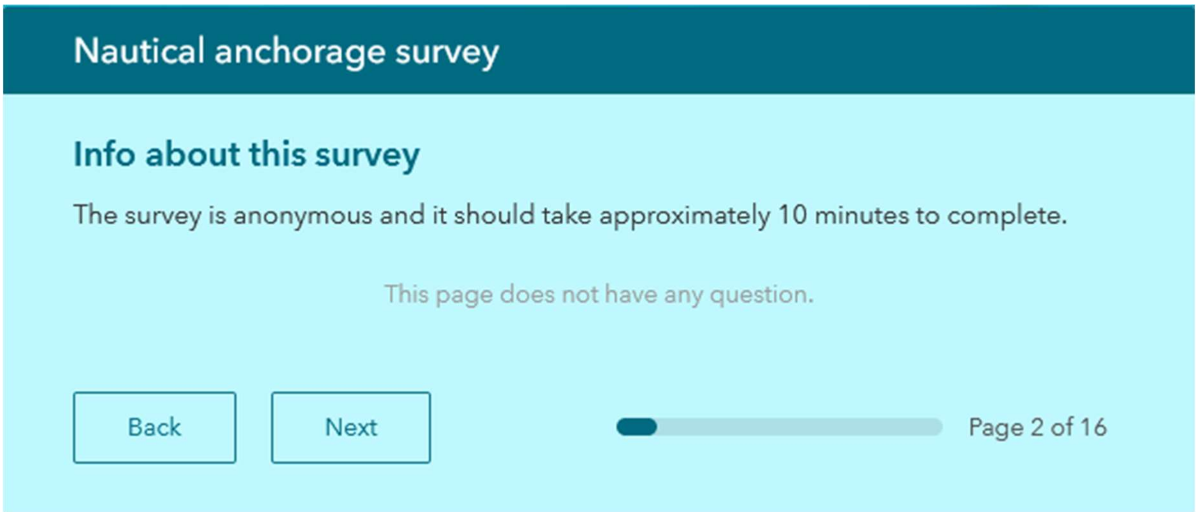
Nautical anchorage survey

Info about this survey

The survey is anonymous and it should take approximately 10 minutes to complete.

This page does not have any question.

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Nautical anchorage survey

General data - Participant information

General data - profession*

What is your profession?

General data - occupation*

How would you describe your maritime (boating) occupation?

- Amateur
- Professional
- Other

General data - ownership of the boat*

Do you own a boat/boats?

- Yes
- No

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Nautical anchorage survey

General data - Participant information

General data - profession*

What is your profession?

_

General data - occupation*

How would you describe your maritime (boating) occupation?

- ○ Amateur
- ◉ Professional
- ○ Other

General data - ownership of the boat*

Do you own a boat/boats?

- ◉ Yes
- ○ No

General data - boat size*

Please enter your boat size?
(Boat size in metres)

123

General data - boat type*

What type is your boat?

- ○ Unpowered or man-powered boats (like rafts, gondolas, kayaks, etc.),
- ○ Sailboat
- ○ Motorboat
- ○ Other

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Nautical anchorage survey

Critera ranking

In the following survey, please rate the weight of certain criteria. The criteria are divided into the general ones, for mooring area selection, and the specific ones, for mooring field selection.

General criteria:

- Safety of Navigation criteria
- Hydrometeorological criteria
- Spatial criteria
- Economic criteria
- Environmental criteria

Weight criteria legend:

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

This page does not have any question.

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Nautical anchorage survey

Safety of Navigation criteria

Please rate the importance of these Safety of navigation criteria.

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

Nautical anchorage - Importance level - underwater installations*

Vicinity of underwater cables, underwater installations and other sites which imply prohibited anchorage.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - potential danger*

Potential danger for a collision, impact, grounding, and other hazards.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - maneuver space*

Enough maneuver space outside the mooring field for vessels that need to manoeuvre.

☆ ☆ ☆ ☆ ☆

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Nautical anchorage survey

Safety of Navigation criteria

Please rate the importance of these Safety of navigation criteria.

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

Nautical anchorage - Importance level - underwater installations*

Vicinity of underwater cables, underwater installations and other sites which imply prohibited anchorage.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - potential danger*

Potential danger for a collision, impact, grounding, and other hazards.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - maneuver space*

Enough maneuver space outside the mooring field for vessels that need to manoeuvre.

☆ ☆ ☆ ☆ ☆

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Nautical anchorage survey

Hydrometeorological criteria

Please rate the importance of these Hydrometeorological criteria.

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

Nautical anchorage - Importance level - shelter*

In the areas as sheltered as possible from the influence of bad hydrometeorological conditions, mostly from the wind and the sea.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - current & tide*

In the area with the least influence of tides, especially of currents.

☆ ☆ ☆ ☆ ☆

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Nautical anchorage survey

Spatial criteria

Please rate the importance of these Spatial criteria.

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

Nautical anchorage - Importance level - distance and depth*

In the area with enough depth, on a safe distance from the shore, other installations, and transit routes of other vessels.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - swing radius*

Swing radius does not cross the field boundaries, nor does it overlap with the swing circles of other vessels.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - occupying space*

Please choose how much space, in your opinion, one mooring field can occupy inside the cove.

-Please select-

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Nautical anchorage survey

Economic criteria

Please rate the importance of these Economic criteria.

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

Nautical anchorage - Importance level - Harbour area*

In the vicinity of harbour area.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - public berths*

Not interfering with existing public berths.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - mainland access*

Having a mainland access without obstruction.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - traffic and other infrastructure*

In the vicinity of roads and other shore infrastructure.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - cost-effectiveness*

Being occupied in line with expectations.

☆ ☆ ☆ ☆ ☆

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Nautical anchorage survey

Environmental criteria

Please rate the importance of these Environmental criteria .

☆ - Very low (1)
☆☆ - Medium low (2)
☆☆☆ - Medium high (3)
☆☆☆☆ - High (4)
☆☆☆☆☆ - Very high (5)

Nautical anchorage - Importance level - Environmental impact*

Reducing the mooring fields (anchorage area) environmental impact.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - Disturbance to seabed*

Avoiding anchors disturbing the seabed by using embedment anchors and anchoring equipment which do not disturb the seabed.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Nautical anchorage - Importance level - Pollutants or waste*

Pollutants or waste being collected from the vessels and appropriately disposed on the mainland.

☆ ☆ ☆ ☆ ☆

Nautical anchorage - Importance level - Local heritage*

Preserving local heritage values as much as possible.

☆ ☆ ☆ ☆ ☆

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Nautical anchorage survey

Drawing on map

In the next part of the survey, it is necessary to manually draw anchorage fields in designated coves.

Drawing hints:

Please use simpler geometric shapes: circle, square, rectangle, or if necessary use a freehand tool.

Before drawing, please read the information about the area (general and nautical).

Do not draw outside the cove area or on land.
Use map zoom (+ or -) and map extend option for better and more precise drawing --->

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Nautical anchorage survey

General information - Lovrečina cove

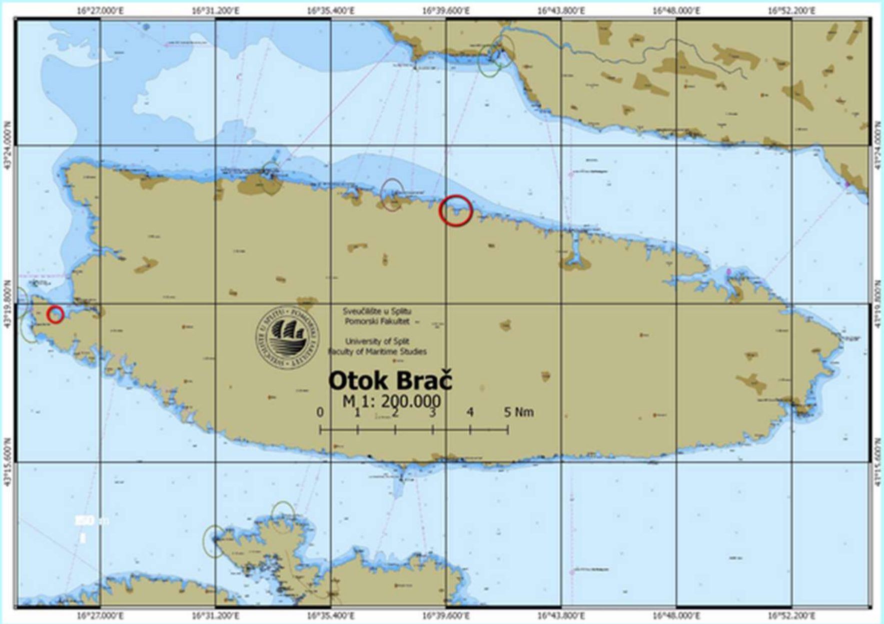
Lovrečina cove is located on the north side of the island of Brač, 1.6 nautical miles east of Postira. At the bottom of the bay there is a large sandy beach.

General map of cove locations

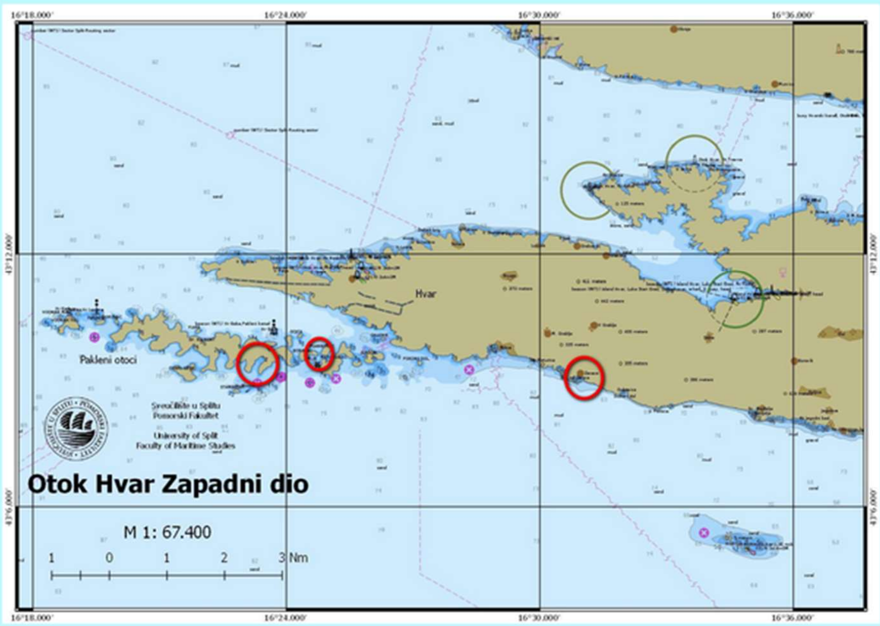
Locations of coves on islands of Brač and Hvar are marked with red circles.

On the island of Brač there are:

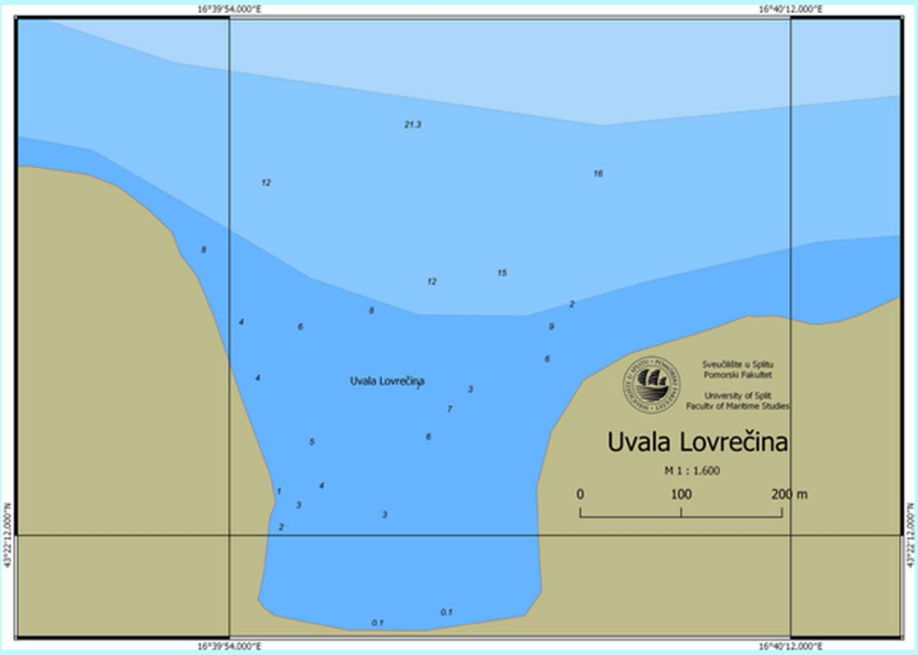
Lovrećina cove (43°22'25.3"N 016°39'01.6"E)
Mali Bok cove (43°19'31.2"N 016°25'20.7"E)



On the island of Hvar there are:
Ždrilca passage (43°09'31.7"N 016°24'52.3"E)
Velo Zaraće cove (43°08'58.2"N 016°30'56.9"E)
Vinogradišće cove (43°09'22.2"N 016°23'19.5"E)



Map of Lovrečina cove

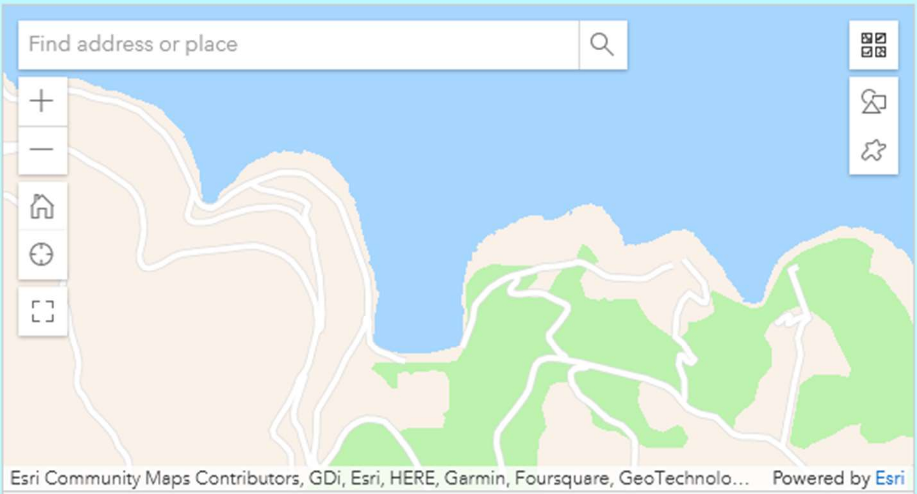


Nautical data - Lovrečina cove

Lovrečina cove is a good anchorage in nice weather. The bay is exposed to NE wind (bura). In the bay, you can anchor on sandy bottom, but you should be careful of the shallow bottom that extends more than 100 m from the shore. There are small piers in front of the houses. On the W side of the bay there is a wharf in front of which the depth is 3 m.

Draw - cove Lovrečina*

Draw the anchorage area on the map.



No geometry captured yet.

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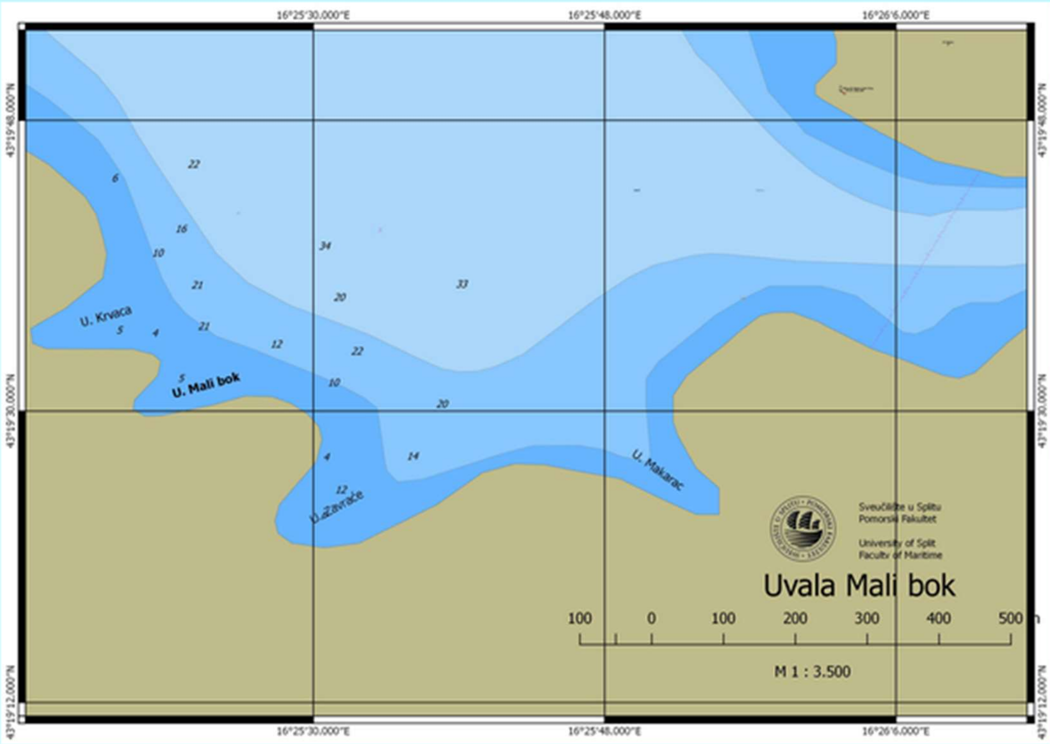
General information - Mali Bok cove

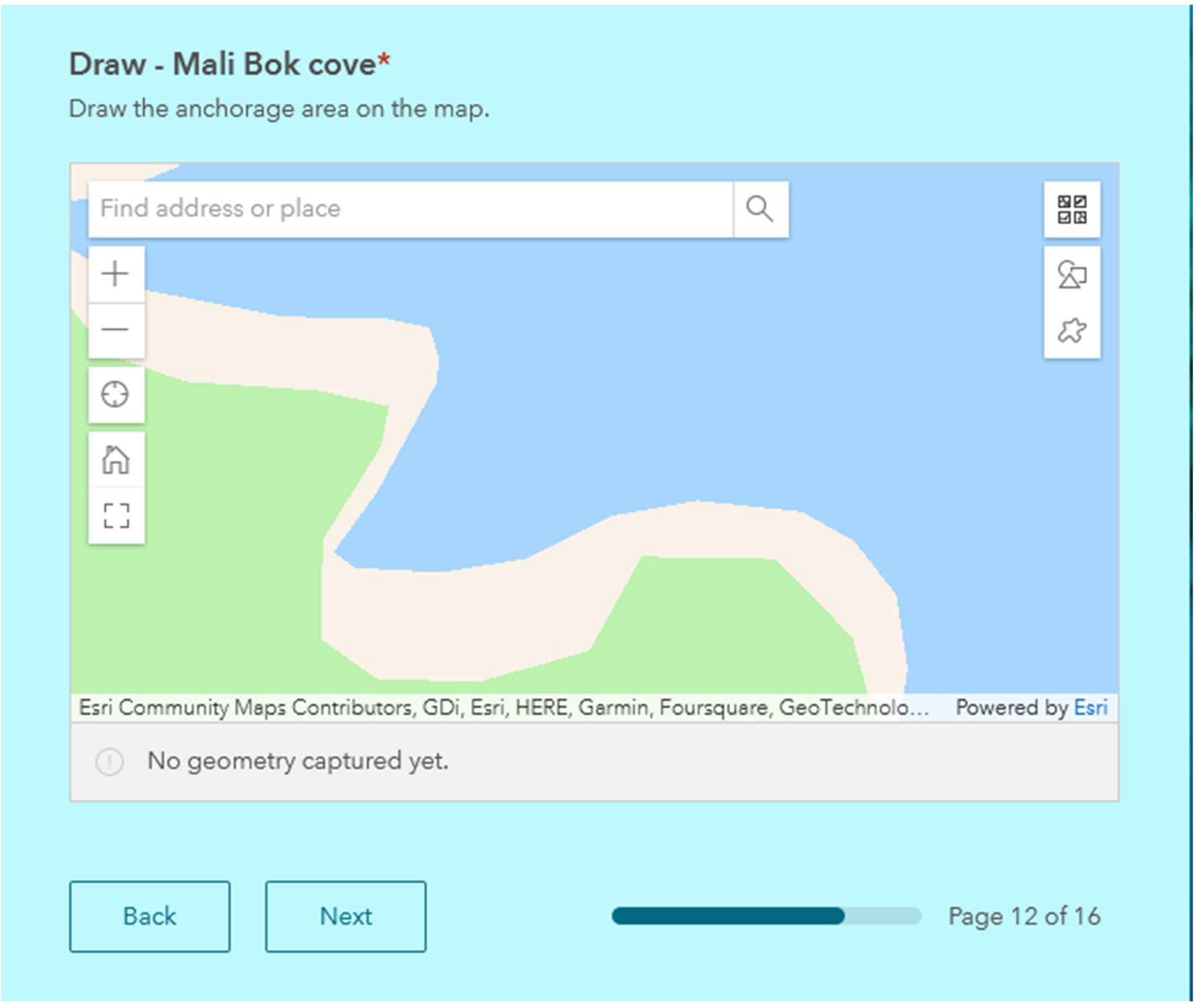
Mali Bok cove is located on the northern side of the island of Brač. The cove is located on the northeastern part of Zaglav Cape at the entrance of the port of Milna on Brač and about 0.6 M northeast of the light on Ražanj Cape. It is oriented towards the northeast. It is the destination of boaters who use it most often as a bathing place during the day.

Map of Mali Bok cove



Nautical data - Mali Bok cove

It is exposed to all winds, especially storms that create strong waves.


Draw - Mali Bok cove*
Draw the anchorage area on the map.
Find address or place
Esri Community Maps Contributors, GDi, Esri, HERE, Garmin, Foursquare, GeoTechnolo...
Powered by Esri
No geometry captured yet.
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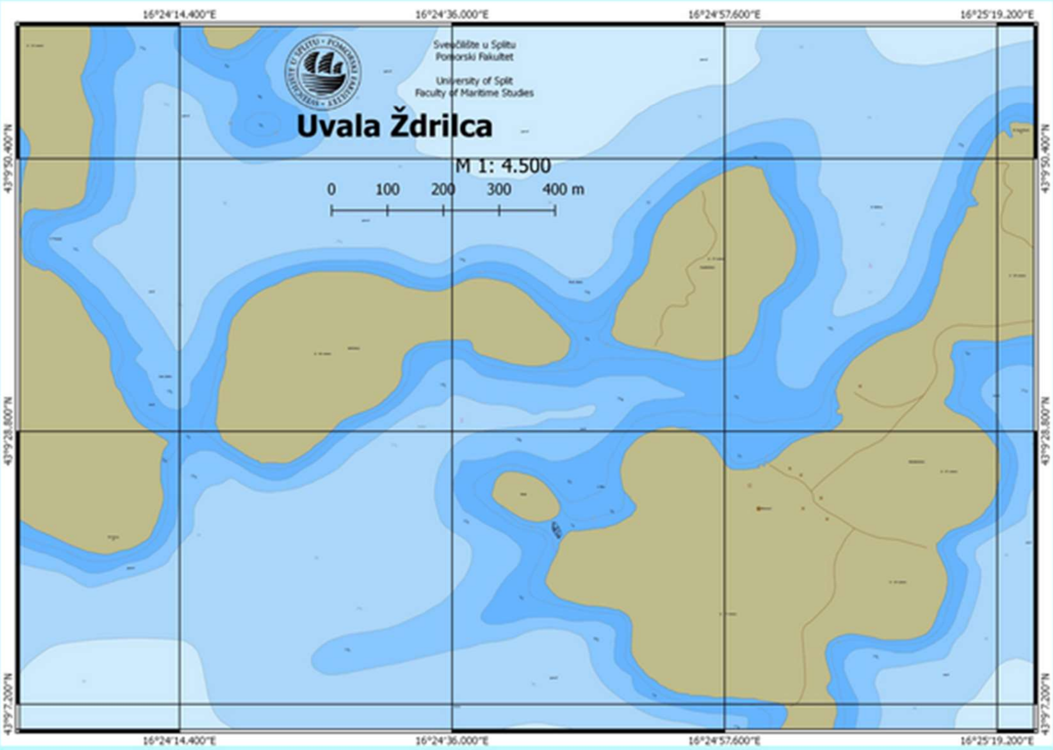
Nautical anchorage survey

General information - Ždrilca passage

The passages between the islands of Sveti Klement, Borovac, Planikovac and Marinkovac are called Velo Ždrilo, Malo Ždrilo and Ždrilca respectively. There are three bays on the islet of Marinkovac: Stipanska on the southern part of the island, and Ždrilca and Mlini on the western part. Ždrilca and Mlini are wooded lagoons with several pebble beaches. During the tourist season, the houses in the bay on the NW side of the island are inhabited. There are several restaurants here. In front of them there are small piers (depth 1.8 m).

Map of Ždrilca passage

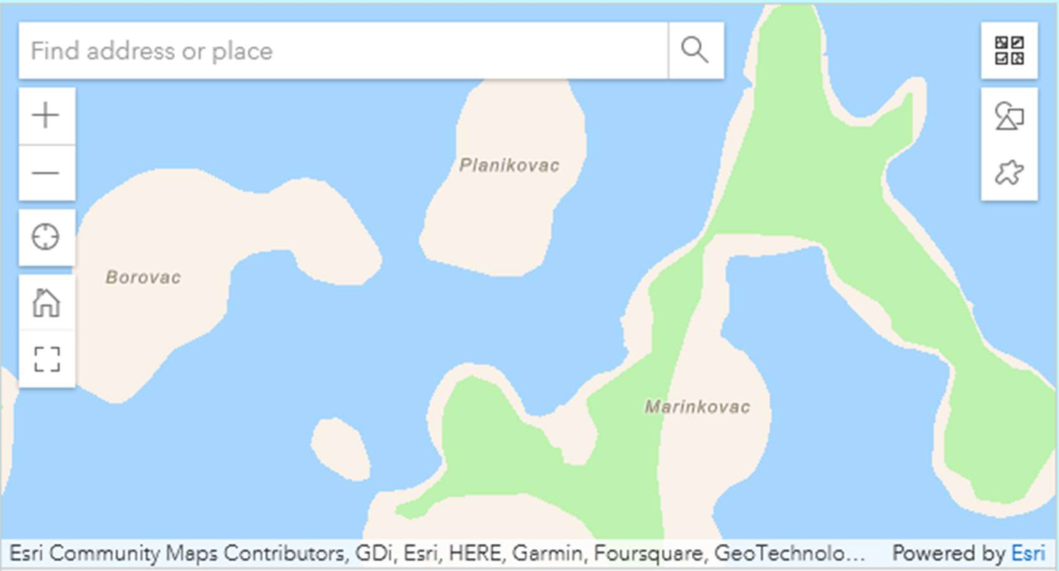


Nautical data - Ždrilca passage

Ždrilca passage consists of three passages between smaller islets. The northwestern passage of Velo Ždrilo is between the islets of Sv. Klement and the islet of Borovac. The depth in the narrowest part of the passage is 5.5 meters. The northern passage of Malo Ždrilo is between the islets of Borovac and the islets of Planikovac. The depth in the narrowest part of the passage is 2.4 meters. The largest and widest passage is Ždrilca passage between the islets of Planinkovac and Marinkovac. The depth at the southern entrance to the passage is 27.5 meters (between the islets of Mlin and Borovac), while in the central part of the passage the depth is 15.4 meters. The lowest depth in the passage is 6.6 meters between the islets of Planikovac and Marinkovac. The depth at the northern entrance is about 12.5 meters. In the passage between the islets of Marinkovac and Planikovac, you should pay attention to the shoals along the shore. For W of passing wind, the speed of the current is up to 4 knots. Along the coast, the depths decrease sharply.

Draw Ždrilca passage*

Draw the anchorage area on the map.



No geometry captured yet.


Draw Ždrilca passage*
Draw the anchorage area on the map.
Find address or place
Planikovac
Borovac
Marinkovac
Esri Community Maps Contributors, GDi, Esri, HERE, Garmin, Foursquare, GeoTechnolo...
Powered by Esri
No geometry captured yet.
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Nautical anchorage survey

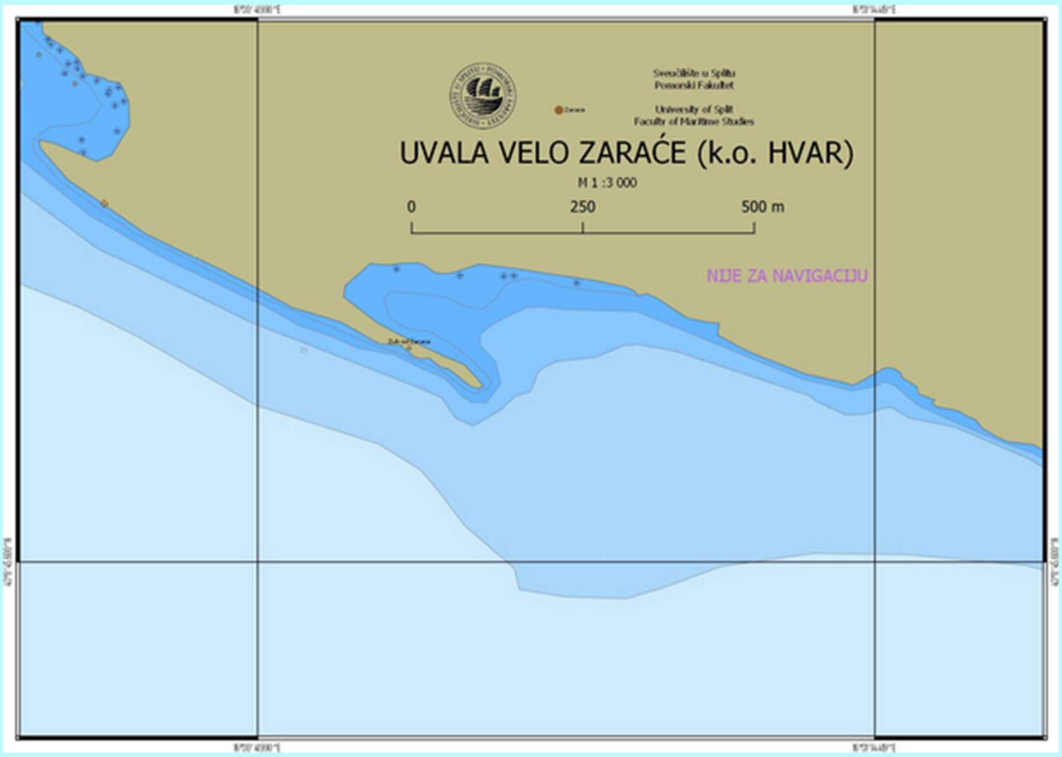
General information - Velo Zaraće cove

Velo Zaraće cove is located on the southern side of the island of Hvar. The bay is surrounded by rocky shores with many cliffs and ridges. The bay is protected by the wide stone promontory Zub, which is a natural breakwater. At the end of the bay there is a small pier and a beach.

Nautical data - Velo Zaraće cove

Velo Zaraće cove is well sheltered from NE to SW winds. It is exposed to winds from E to SE direction, which can cause stronger and very wavy seas.

Map of Velo Zaraće cove



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Draw Velo Zaraće cove*

Draw the anchorage area on the map.

No geometry captured yet.

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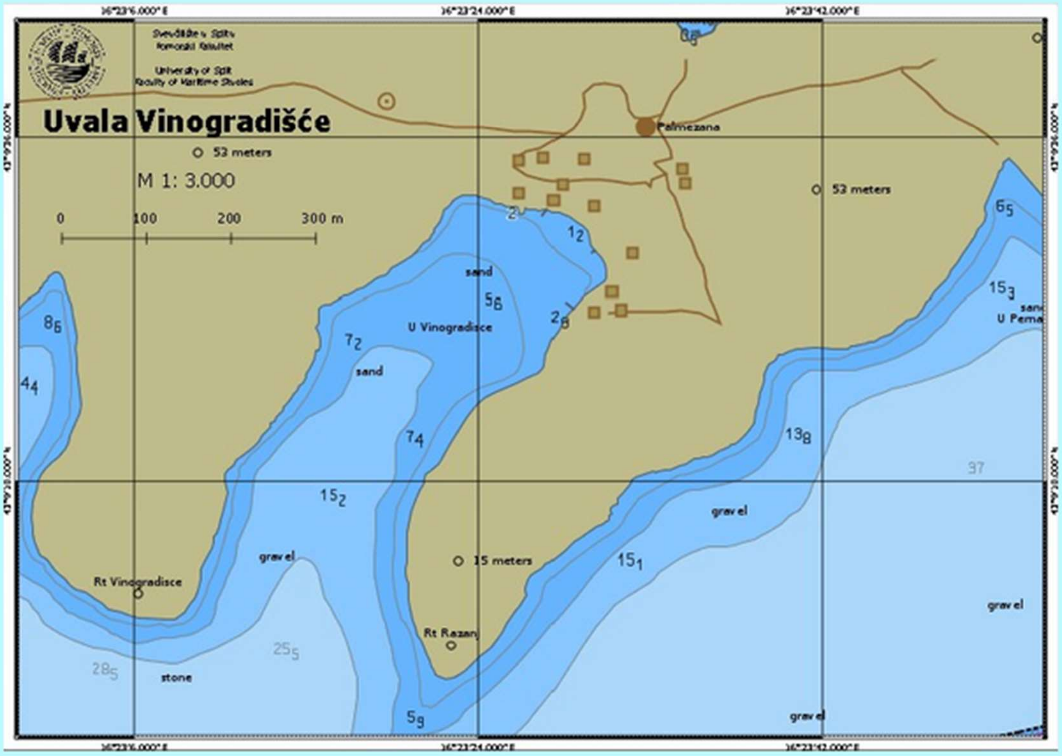
Nautical anchorage survey

General information - Vinogradišće cove

Vinogradišće cove is located on the southeastern part of the island of Sveti Klement. Sveti Klement is the largest island in the Pakleni otoci island group. On the NE part of the island is the bay of Palmižana where the ACI marina is located. The island is surrounded by many rocks and shoals, so it is necessary to pay close attention to them when sailing around it. Vinogradišće cove is open to the southwest. At the bottom of the deep bay there are several small restaurants.

Map of Vinogradišće cove

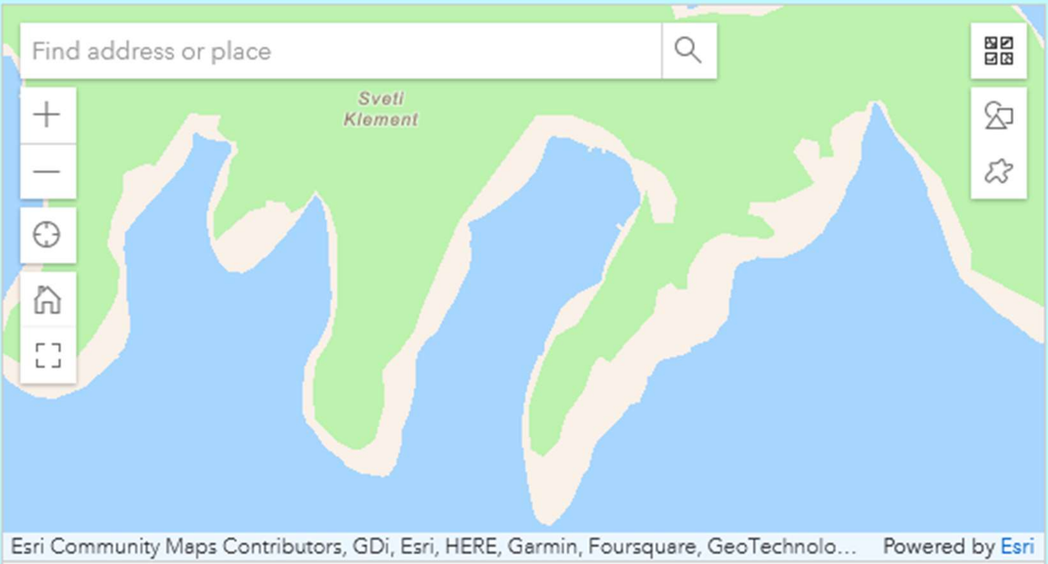


Nautical data - Vinogradišće cove

About 0.5 NM SW from the entrance to Vinogradišće cove is the islet of Stambedar. To the east of it there are the cliffs of Plocica and an unmarked 4 m shallow beach. Smaller boats can anchor in the bay in good weather. The far end of the bay is shallow, and there are several smaller piers in front of the restaurant. The cove is somewhat sheltered from the SW wind by the islet of Stambedar. The Vinogradišće cove area is well sheltered from all winds except from the southern quadrant. The lower part of the cove is also sheltered from the SE wind.

Draw Vinogradišće cove*

Draw the anchorage area on the map.



No geometry captured yet.

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Nautical anchorage survey

Comments

Comments or suggestions

You are about to submit your response to this survey.

If you have any further information you wish to provide, please do so below.

When you are ready to submit, please use the button at the bottom of the page.

Thank you.

Danijel Pušić MBsc
Senior Lecturer
University of Split - Faculty of Maritime Studies

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