Conceptual framework of a Global Yacht Positioning System in Poland

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Abstract

The sailing market continues to develop rapidly and has a high growth potential. Sailing is one of the most popular types of recreational activity in Poland due to an abundance of lakes, including the Great Masurian Lakeland Trail which received a special mention from UNESCO. The development of nautical tourism requires effective organizational and technical solutions. The absence of a public mooring information system in Poland's inland harbors has prompted the development of the Global Yacht Positioning System (GYPS) for mobile devices. The design process was preceded by a survey of sailors and marina operators to identify their needs and expectations, as well as an inventory of marinas in the Polish region of Masuria. The developed prototype system is a mobile application that relies on data transmission, communication and satellite technologies. The proposed solution is a convenient tool that will facilitate the operations of inland harbors and improve navigation safety.

Keywords Sailing · Nautical tourism · Ports · Marinas · Global Yacht Positioning System (GYPS)

Introduction

Inland sailing or nautical tourism is a form of active water-based tourism. Nautical tourism entails trips outside the place of permanent residence that last more than 1 day and involve sailing activities (Nowacki 2015). Sailing activities generally involve yachts. Nautical tourism is an important branch of the economy that generates high profits (Alcover et al. 2011; Bicak et al. 2006; Chen et al. 2016; Dimou and Vandrou 2018; Ioannidis 2019; Kaup 2010; Luković 2012; Łapko and Lučić 2019; Payeras et al., 2011; Santos and Perna 2018; Sevinç and Güzel 2017).

The growing popularity of nautical tourism necessitates the development of sailing infrastructure along the shores of inland water bodies. The main components of sailing infrastructure are ports and yacht harbors. Harbors are basins for mooring yachts and other recreational vessels in docks that should enable safe mooring of up to 50 vessels (Kulczyk et al. 2016). Large harbors are classified as yacht ports. Marinas are special types of harbors that include permanent or temporary accommodation for tourists.

Ports and marinas offer a variety of basic and complementary services. Basic services include berths for mooring yachts. Tourists who pay a mooring fee have access to port services, complementary services, and charter services.

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Port services involve access to bathrooms, drinking water, electricity, and fuel docks, as well as waste collection services. Slipping facilities and winter mooring services are also available. Complementary services include restaurants, retail outlets and tourist attractions.

The nautical tourism model in Poland continues to evolve. Traditional sailing clubs that operate own yachts as well as amateur sailing clubs are being gradually replaced by charter tourism where yachts are provided and maintained at a fee by professional operators (Nowacki 2015). Charter tourism is increasingly popular due to the high cost of purchasing and maintaining a yacht. Under a charter agreement, tourists hire yachts in return for the charter fee. Charter agreements can be concluded for the temporary hire of a yacht for private recreation and for organizing cruises (Łapko 2018).

The advancement of information, communication, and satellite technologies has led to the development of modern tools that are increasingly often used in sailing and yachting tourism (Kammler et al. 2019; Pranita 2020; Wang et al. 2016). Rapid population growth and the increase in tourist traffic often compromise the efficiency of land, water, and air transport systems (Al-Turjman and Malekloo 2019). Traffic jams contribute to environmental pollution, waste of time, and energy (Mao et al. 2012; Łapko et al. 2019). These problems necessitate the development of tourist infrastructure and tools that facilitate travel (Wiegman et al. 2015; Dreizis and Potashova 2018). Intelligent solutions that guide users to harbors and marinas play an increasingly important role in nautical tourism. Such solutions are based on:

- Global Navigation Satellite System (GNSS) sensors and receivers that increase safety in inland sailing (Feriol et al. 2020; Heßelbarth et al. 2020),
- blockchain technology (Ahmed et al. 2019; Al Amiri et al. 2020),
- mathematical models for optimizing the location of mooring facilities (Wang et al. 2019),
- storage and management of data used for Marine Spatial Planning (Flynn et al. 2021),
- geographic information system (GIS) tools for harbor management (Elbeih et al. 2019; Akyrek and Bolat 2020; Nur et al. 2020).

Research into intelligent sailing solutions has also been conducted in Poland (Bałdyga and Lichy 2017; Burciu et al. 2017; Łubczonek et al. 2012; Miler and Bujak 2012; Popielarczyk & Templin 2014; Stulak-Wójcikiewicz et al. 2019; Stulak-Wójcikiewicz et al. 2020; Valenta and Kijas 2010). According to Migdał and Hącia (2019), information systems in Polish ports and marinas require improvement due to growing volumes of traffic. The development of nautical tourism also requires effective organizational and technical solutions, in particular in stationary facilities such as

marinas (Wiktorowska-Jasiak and Tołkacz 2013). A research project financed by the European Space Agency (ESA) with the aim of developing a prototype solution based on GNSS positioning was initiated in 2017.

Inland sailing is developing rapidly in Poland, and the number of yachting enthusiasts continues to increase each year. Thousands of yachts cruise the largest Polish lakes in summer. As a result, vacant berths are increasingly difficult to find, in particular in peak season. Tourists are often forced to choose less attractive ports or spend the night on the yacht in unguarded locations and without access to tourist infrastructure. The absence of a public mooring information system in Poland's inland harbors has prompted the development of the Global Yacht Positioning System (GYPS) for mobile devices. Navigation and berth booking applications (such as Żegluj developed by Infeo Marcin Gryszko, or GalileoNaut developed by JOCS) are also available on the Google Play website (<https://play.google.com/>, accessed on 12 December 2020).

This study proposes an innovative solution for optimizing the operations of yacht harbors and facilitating safe and convenient inland navigation. The proposed solution is an integrated system that combines a berth management application, a navigation application, navigation devices, and a berth booking application with access to a cloud database. The designed system is addressed to both port managers and sailors. This convenient sailing tool improves the operations of inland harbors and increases navigation safety.

Inland sailing in Poland

Inland sailing is a popular type of active recreation in Poland. The relevant infrastructure is well developed due to an abundance of inland water bodies in the country (Tomik and Kosmala 2018). Poland has more than 7000 lakes (0.9% of the national territory is occupied by lakes), where the regions of Pomerania and Masuria (Land of a Thousand Lakes) are the most popular yachting destinations. Masuria is the world's largest market of inland yacht charter tourism (Sądecka and Janusz, 2018).

The navigable regions presented in Fig. 1 are characterized in Table 1. The region of Pomerania is situated in northern Poland on the Baltic coast, and it comprises the voivodeships of Western Pomerania and Pomerania. The region of Masuria in north-eastern Poland covers the voivodeships of Warmia-Masuria and Podlasie. Masuria, also known as the Land of a Thousand Lakes, received a special mention in UNESCO's New 7 Wonders of the World campaign.

According to the Report on the Polish Sailing Market (2016), around 540,000 Poles participate in recreational, sports, professional, and competitive yachting activities (Table 2). The number of individuals who claim to be able to steer a yacht is more than 2.5 times higher. Around 3.4

Fig. 1 Main navigable regions in Poland — percent of the voivodship territory occupied by lakes. Source: own elaboration (blue color-lakes cover more than 2% of the voivodeship area)

Table 1 Characteristics of the main navigable regions in Poland

Parameter	Pomerania	Masuria
Number of lakes larger than 1 ha	3300	2000
Access to the Baltic coast	Yes	No
Charter companies	40	98
Large yacht manufacturers	5	6
Yacht service companies	7	8
Percentage of Polish sailors choosing the region	20%	50%

Report on the Polish Sailing Market (2016)

Table 2 Types of sailing activities undertaken in Poland

Population	Percentage of total population	Type of activity
0.5 million	2%	Participation in races, competitions, and contests
1.3 million	5%	Trained navigators, skippers
3.4 million	14%	Recreational active crew
5.1 million	19%	Recreational passive crew
8.1 million	30%	Any type of sailing experience

Report on the Polish Sailing Market (2016)

million Poles declare to have sailing experience as crew members who performed various deckhand duties. More than 5 million Poles participate in leisure cruises as passive crew members at least every few years. This implies

than 70% of Poles have had some kind of sailing experience. A demographic analysis indicates that the largest group of Polish sailors is composed of men aged 25–49 who have higher financial status, post-secondary education, use new technologies, and social media.

Sailing activities in Poland involve mainly inland sailboats and sailing yachts. Inland sailing is the most popular type of nautical tourism and the only type of nautical activity that does not require a professional license. Most yachts are registered on a volunteer basis (excluding vessels with haul length exceeding 12 m). Unregistered yachts have to be labeled (Nowacki 2015). Most yachts are chartered. The types of yacht charter companies operating in Poland are divided according to Łapko (2018): area (domestic, international, multiterritorial), ownership (offering own yachts, agents—offering private yachts or yachts of other companies, offering own agents yachts), and legal status (private businesses, clubs and sailing associations, towns and municipalities, sailing ports, other).

The Great Masurian Lake Trail with a total length of 126.4 km (and branch trails with a combined length of more than 200 km) is one of the most popular sailing trails in Poland. It connects the largest Polish lakes of Śniardwy, Mamry, and Niegocin. The trail features the highest number of yacht charter companies and inland harbors in Poland. According to the Report on the Polish Sailing Market (2016), Masuria is the preferred destination for more than 50% of Polish sailors. Each year, the region attracts more than one million domestic tourists and around 200,000 foreign visitors.

The Polish sailing market continues to develop rapidly and has a high growth potential. In the digital era, the sailing market should receive support from modern technologies that rely on Internet access. Various types of solutions have been introduced for the needs of nautical tourism in Poland, including yacht charter websites (including in Masuria, zegluj.pl), websites with information on the availability of sailing infrastructure and facilities (such as sailing.org.pl developed by the Polish Yachting Association), and mobile applications (Click&Boat, Taider maps of Masurian lakes, Navisail, and NaviApp Masuria). However, there are no tools or applications for finding and booking berths in Polish yacht ports.

Research procedure

The development of the Global Yacht Positioning System (GYPS) was preceded by a survey of two respondent groups — sailors and yacht/sailboat charter companies — and interviews with harbor operators. The proposed GYPS solution will target mainly sailors. Other prospective users will be yacht charter companies and marina operators. A survey

was carried out to collect information about the respondents' sailing experience, use of modern technologies and tools, potential demand for a berth booking system, and the users' expectations concerning the application's functionality. The survey questionnaire is presented in the Supplementary information. The survey was conducted at the end of 2018 and at the beginning of 2019, and it involved sailors visiting the Great Masurian Lakeland Trail and yacht charter companies operating in the region. The respondents were surveyed during direct interviews or filled out the questionnaire online (on social media platforms).

In the second stage of the study, marinas in the Great Masurian Lakeland Trail were inventoried in 2017 during a field study. The inventory was updated in 2019. The results of the inventory are presented in Sect. 3.2 and in the Supplementary information.

The GYPS concept was developed in the third stage of the study. System architecture was designed, and its functionality was described. The main components of the proposed system, and the links and communication between these modules were also described. The structure of the designed application was developed based on the information collected during surveys and interviews in the first two stages of the study. A feasibility study was also conducted, and it accounted for the existing technical limitations and sailor preferences.

In the last stage of the study, a GYPS application prototype was developed and tested in the Great Masurian Lakes. The research methodology is presented in Fig. 2.

In the process of developing the GYPS application, the researchers remained in contact with the surveyed respondents to collect opinions about the designed tool. This approach supported the identification of the unique needs of each user group. The proposed system will create a win–win situation where port operators are provided with a reliable

tool for managing mooring space, tourists do not have to waste previous time searching for vacant berths, and charter companies can monitor their fleet in real time.

Results

Survey results

The first survey involved 112 sailors. The respondents completed a questionnaire to provide information about their demographic profile and sailing abilities. The survey questionnaire is presented in the Supplementary information. The majority of the respondents were professionally active persons (50%) and university students (40%). Around 45% of the surveyed individuals sailed on lakes at least once a year, whereas 42% of the respondents took part in sailing trips more than once a year.

The survey revealed that GPS navigation applications were used often by only 31% of the respondents and very rarely by as many as 40% of the surveyed subjects. Analog maps were the preferred navigation tool for 33% of the respondents. The surveyed sailors had smartphones with Android (72%) and iOS (22%) operating systems. The respondents claimed to have very good and good Internet access (76%). More than 70% of the polled sailors frequently downloaded smartphone applications, which validates the assumption that the proposed GYPS application should target smartphone users. Most respondents (70%) downloaded free applications, which should be taken into consideration in the process of pricing the product. According to 71% of the surveyed sailors, EUR 3 would be an acceptable price.

The scarcity of vacant berths during the sailing season was one of the main problems reported by the surveyed respondents. The GYPS application will meet the

Fig. 2 Research methodology and the progress made in the development of the system technology. Source: own elaboration

expectations of 55% sailors. In the respondents' opinion, the berth booking option will be one of the most important functionalities of the designed system. Additional modules (weather forecast, news service) are not essential, but will add value to the product. The graphic interface should be simple, intuitive and easy to use.

The second group of respondents included 10 yacht/sailboat charter companies which were surveyed to elicit information about the Polish charter market. The survey questionnaire is presented in the Supplementary information. The majority of the interviewed companies owned 1 to 3 vessels. Average vessel occupancy rates (51–75%) were reported by 73% of the polled companies, and high occupancy rates (more than 76%) were indicated by the remaining charter companies. These results indicate that the demand for chartered yachts is very high in Poland. According to all respondents, the average charter period was 4 to 7 days. Repeat customers account for a high percentage of clients in every season. Most respondents reported 40–50 of regular customers per season.

According to the surveyed companies, the charter season lasts from 1 May to 30 September, with a peak in the summer holiday months (July and August). All respondents paid for advertising services. Most advertisements targeting sailors were purchased on *mjacht.pl* and *interjacht.pl* (34%) and *mazury.info* and *mazury.pl* (28%) websites. Annual spending on advertising reached EUR 250–500 in 45% of the surveyed companies, and it exceeded EUR 500 in 36% of the polled businesses.

Results of marina inventories

The results of the harbor inventory are presented in detail in the Supplementary information. A total of 38 harbors with 3475 berths were inventoried. The spatial configuration of marinas is presented in Fig. 3. Assuming that yacht occupancy is around 70% between 1 May and 1 October, berth occupancy should also approximate 70%, which indicates that 2432 berths should be occupied daily. Most sailing trips last 7 days; therefore, 21 trips can be organized between 1 May and 1 October. Every 7-day trip involves 2432 yachts and potential users, which translates to more than 50,000 users of the designed application.

Features of the GYPS application.

The results of the conducted surveys were used to optimize the operation, functionality and accessibility of the proposed GYPS application. Survey findings indicate that the designed application should be compatible with the major mobile operating systems. The navigation application should rely on interactive maps (such as Google Maps). The required databases should be updated automatically. The application should notify users of potential Internet connection problems in areas where mobile signal reception is

weak. According to the interviewed marina operators, the application should be available for both smartphones and computers.

The application will contain two modules: software for sailors and software for marina operators. The results of the conducted surveys were analyzed to identify three groups of features in the GYPS application (Table 3).

The above groups of features were taken into consideration in the process of designing the architecture of the GYPS application. The GYPS will be a mobile application featuring several modules connected via communication and data transmission systems. The system will recognize changes in network topology when users change their location, as well as changes in the availability of berths in marinas.

The GYPS will feature several elements: mobile devices used by sailors, mooring service system, database, external sources of information about weather conditions, weather forecasts, local events, and a satellite tracking module. These elements will be connected via transmission media, such as mobile networks and mobile Internet (3G/4G/5G). The structure of the GYPS is presented in Fig. 4.

A database will be the key element of the GYPS. The database will gather information about points of interest (POI), and it will provide users with information about vacant berths in real time (1). Docking stations in marinas will be labeled as available, unavailable, or reserved. Berths will be labeled as available when vessels are not moored in the selected location. When a given berth is selected, the user has to navigate to the dock, and the selected berth will be labeled as reserved until the vessel reaches its destination. Upon arrival, berth status will be changed to “unavailable” by the marina operator. If users intentionally block mooring spaces (the vessel does not sail straight to the booked berth), the operator can reserve the berth and temporarily ban the user from booking mooring space in the marina. The information about available berths will be transmitted from the marina's administration system to the database, and when a booking is made, the relevant information will be sent from the database to the marina operator.

Sailors will be the main recipients of the GYPS database. The application will determine a vessel's location based on GNSS trace data (2). The system will display the nearest marina based on the distance between the yacht and the harbor, but the final choice will be made by the user. The user will download information about vacant berths in a selected marina, local events, weather, and other types of data (such as mooring fees) from the database (3). Current weather and weather forecasts will be displayed based on the yacht's position. The relevant information will be downloaded directly from dedicated servers (4).

The user will also have access to weather data from public weather services (5). Information about local events can be added to the system by the administrator (6). One-way

Fig. 3 Location of marinas in the Great Masurian Lakeland. Source: own elaboration

Table 3 Features of the GYPS application

Essential features	Optional features	Future features
<ul style="list-style-type: none"> - Compatibility with the major mobile operating systems (Android, iOS, Windows); - Users (marina operators) should be able to enter information about the marina (number of available berths, accommodation, facilities, prices); - Booking berths in a selected marina (with booking confirmation); - The berth layout map should be displayed when the yacht approaches the marina (at a given distance from the marina); - A map of entry and exit ports in the marina should be displayed; - The application should be available in several language versions; - The application should enable rapid dialing of emergency numbers 	<ul style="list-style-type: none"> - Search for berths in different price categories; - Search for berths in marinas with vacant rooms; - Description of local tourist attractions; - Description of accommodation services in the marina; - Marina maps; - Search for berths based on the estimated arrival time (the estimated arrival time is computed by an algorithm based on weather conditions); - Marina operators should be able to add information about discounts; - Sailors should be able to review the visited marinas; - Search for berths in quiet and loud zones; - The application should monitor mooring time 	<ul style="list-style-type: none"> - Booking berths next to friends (community of application users); - Tracking friends; - Initiation of group meetings; - Online camera with a view of the marina

Own elaboration

communication will be established between the above information sources and the main database. The connections between information services that transmit data in the GYPS is presented in a diagram in Fig. 5.

GYPS application prototype

The GYPS technical analysis was developed with the Android Studio environment using Java, PHP, and MySQL. Based on the identified system requirements, an application prototype was developed to test the functionality of all features and the ease of navigation on mobile devices. The prototype solutions in the sailing module of the application are presented in Fig. 5.

The heart of the system is a database where data on the status of individual berths is stored. The database should provide real-time data synchronization — every time data changes, any connected device receives that update within milliseconds. Also, after connectivity is reestablished, the client device receives any changes it missed, synchronizing it with the current server state. In other situations a browser-based service and a key module for changing the state of an object in a database in dynamic mode should meet the Database Server Requirements:

- Built-in high availability.
- Data protection using automatic backups and point-in-time-restore.
- Automated maintenance for underlying hardware, operating system and database engine to keep the service secure and up to date.
- Elastic scaling within seconds.
- Enterprise grade security.
- Protect sensitive data at-rest and in-motion.

In Fig. 6, the default application icon is presented on the screen of a real mobile device. When the application is opened, a list of harbors available in the system is displayed on the screen. This part of the application consists of two elements: graphics and descriptive text (Fig. 6a). Window (Fig. 6b) displays three types of important information: the name of the marina, the number of free berths, and the user's distance from the marina. The red anchor icon denotes the absence of free mooring spaces in a given harbor.

The following information is displayed when the user taps the icon of a selected marina: geographic longitude and latitude, water level, harbor sign, and identification number. The application communicates with the database and downloads current information about available berths. Based on the ID of the selected harbor, the application selects berths that correspond to user-defined parameters and displays a list of matching berths in the window. Icons denoting the occupancy status of berths are displayed in three colors (Fig. 6c):

Fig. 4 Structure of the GYPS.
Source: own elaboration

- (1) green icon – berths available, booking and navigation possible,
- (2) red icon – berths are not available, booking and navigation not possible,
- (3) purple icon – berths available but cannot be booked; only authorized sailors can enter the harbor.

Information about the maximum yacht length, harbor coordinates, and harbor ID is displayed next to the icon.

When the user selects a mooring place, the application will display the occupancy status of the chosen berth. Berth status (free/occupied) is displayed on the screen of the mobile device. The maximum yacht dimensions, harbor coordinates, and harbor ID are downloaded from the database and displayed as text. A short description of weather conditions at the point of destination with a weather icon and air temperature are displayed on the right side. Depending on the occupancy status of the chosen berth, two types of options are displayed at the bottom of the screen:

- enter a code to unlock an unavailable berth (Fig. 6d),
- navigate to berths that are available/not locked (Fig. 6e).

If the entered code is correct, a “Navigate” button will appear at the bottom of the screen (Fig. 6e), and the user can navigate to the chosen destination with the use of the GYPS application.

The application features two navigation modes. The first mode can be used to navigate to the selected destination based on the spatial orientation of the mobile device. A digital compass with a north mark arrow and a magnetic needle assists the user in the navigation process (Fig. 6f). In the second mode, the user can navigate based on the vessel’s position on the map and the plotted course. This mode is activated by tapping the “Show map” button (Fig. 6g). The map and navigation parameters, including the vessel’s current position, previous position, distance to destination, course, and speed, are displayed on the screen.

The second application module, GYPS Marina Manager, is addressed to marina operators, and it is used to change

Fig. 5 Diagram of connections between information services that transmit data in the GYPS. Source: own elaboration

the occupancy status of berths in the harbor. This module is an integral part of the GYPS, and it features two functionalities: a management tool (Fig. 6h) and a docking tool (Fig. 6i). The management tool enables the user to log in and manage harbors. To log in and download information from the database, the user has to enter the marina's ID and the password. The docking tool is used to change the occupancy status of berths in the marina and to enter vessel parameters for each berth (Fig. 6f, g). The ID in the "Docking station ID request" field is set based on the operator's position, and the ID of the nearest docking station in the harbor is displayed. The database is updated automatically. Instead of entering the ID manually or selecting the ID from a list, the operator can approach a given berth and set the selected parameters.

If the selected berth is available, the operator can enter docking time, yacht data, access code (which enables the sailor to access the berth), number of passengers, and change the berth's status from available to unavailable. If the berth was booked, the operator can change docking time and

the yacht's parameters. When the vessel leaves the harbor, the operator can change docking time to NULL, delete the access code, and change the berth's status from unavailable to available. Figure 7 shows the use of the application during internal testing.

Summary and conclusions

The prototype of the designed system and mobile application was tested under real-life conditions. In addition to the navigation process, navigation data were also implemented in a text file. The application creates the gypsData catalog where coordinates and navigation data are stored. These data can be further used to assess the navigation process and its accuracy. An option for archiving the information about the occupancy status of berths will be introduced in the future. Historical data will be stored in separate tables for inventorying the available mooring spaces. These data will be

Fig. 6 Application window. Source: own elaboration

Fig. 7 Use of the application during internal testing: **a** the measurement team during testing of the application, **b** the smartphone and GNSS navigation receivers used during the tests, **c** the recorded trajectory of the boat during the test measurements

highly useful in the process of expanding and upgrading harbors, and they can also be used by marina operators to plan their pricing strategies. Based on the gathered data, operators can search for correlations between sailing seasons, local events, the availability of technical and social infrastructure, and harbor occupancy rates. The results will constitute highly valuable inputs for planning management and marketing operations and attracting tourists.

System features and user requirements were assessed by surveying the employees of yacht marinas in Giżycko, Pisz, and Ruciane Nida in the Great Masurian Lakeland Trail (boatswains, administrative personnel, managers). The respondents were asked to voice their opinions on

berth booking solutions, the technical aspects of the GYPS application, and the resulting benefits. The proposed system and application were met with a positive response. Harbor employees also contributed some ideas on how the application's functionality could be improved:

- The application should monitor the number of passengers entering the marina. This solution would optimize the workload in successive sailing seasons;
- The application should generate sound alerts and warnings when a berth is occupied and vacated;
- Yacht and passenger data should be kept in strict confidence.

The GYPS application can be expanded to include additional modules supporting communication between users and the collection of information about POI such as rooms, camping sites, local attractions, or navigation hazards.

The validity of the data accumulated in the database poses a certain challenge. When the number of users is high, the information in the database will change rapidly. Several minutes can pass between the moment data is downloaded from the database and the moment the user's location is tracked by a GNSS receiver. Therefore, the user should be able to refresh the data downloaded from the Internet. The age of data in the system is also an important consideration. The downloaded data should be valid to provide users with reliable information about the availability of berths in marinas.

A prototype system and application for managing mooring services and booking berths were developed based on the opinions and preferences of the surveyed sailors, yacht charter companies, and marina operators. The results of the conducted surveys, field interviews, and the inventory of mooring spaces and facilities in marinas located along the Great Masurian Lakeland Trail indicate that the proposed application will facilitate the search for vacant berths and the management of mooring spaces in yacht harbors. As a result, this easy navigation and booking tool is likely to increase customer satisfaction. This is a very important consideration because satisfied tourists are more likely to return to the same location in the following season and generate profits for yacht charter companies and harbor operators.

The development of 5G and IoT networks will be the future of similar solutions and will cause their large-scale use. At the same time, it will eliminate most of the technical limitations related to data transfer.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12518-021-00413-z>.

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Declarations

Conflict of interest The authors declare no competing interests.

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References

- Ahmed S, Rahman MS, Rahaman MS (2019) A blockchain-based architecture for integrated smart parking systems. *Proceedings 2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops) IEEE, Kyoto, Japan*, 11–15 March, 177–182. <https://doi.org/10.1109/PERCOMW.2019.8730772>
- Al Amiri W, Baza M, Banawan K, Mahmoud M, Alasmay W, Akkaya K (2020) Towards secure smart parking system using blockchain technology. In: *Proceedings 17th Annual Consumer Communications & Networking Conference (CCNC)*, 10–13 January, Las Vegas, USA. <https://doi.org/10.1109/CCNC46108.2020.9045674>
- Alcover A, Alemany M, Jacob M, Payeras M, García A, Martínez-Ribes L (2011) The economic impact of yacht charter tourism on the Balearic economy. *Tour Econ* 17(3):625–638. <https://doi.org/10.5367/te.2011.0045>
- Akyrek E, Bolat P (2020) Ranking port state control detention remarks: professional judgement and spatial overview. *Preprints* 2020010190, <https://doi.org/10.20944/preprints202001.0190.v1>
- Al-Turjman F, Malekloo A (2019) Smart parking in IoT-enabled cities: a survey. *Sustain Cities Soc* 49:101608. <https://doi.org/10.1016/j.scs.2019.101608>
- Bałdyga S, Lichy K (2017) “Wykorzystanie algorytmu a-star w wyznaczaniu tras na akwenach wodnych” [Use of a-star algorithm in the design of water vessels]. *Zeszyty Naukowe Wyższej Szkoły Informatyki* 16(1):5–24
- Bicak HA, Altınay M, Aksugür E, Günyaktı A, Katircioglu S (2006) Could yacht tourism be an alternative tourism potential in North Cyprus? *Tour Mar Environ* 3(1):49–57. <https://doi.org/10.3727/154427306779380284>
- Burciu Z, Świński R, Lipińska K, Jamry A (2017) Nowoczesna żegluga śródlądowa jako cel przedsięwzięcia horyzontalnego na rzecz Inteligentnej Specjalizacji Pomorza: Technologie offshore i portowo-logistyczne. *Gospodarka Wodna* 8:232–237
- Chen J, Balomenou C, Nijkamp P, Poulaki P, Lagos D (2016) The sustainability of yachting tourism: a case study on Greece. In: *Conference Proceedings 56th Congress of the European Regional Inclusive? Association: "Cities & Regions: Smart, Sustainable, Inclusive?"*, 23–26 August 2016, Vienna, Austria, 1–16
- Dimou I, Vondrou, V (2018) Yacht tourism in Greece: current issues and prospects for development. *Conference Proceedings TOUR-MAN "In search of excellence in tourism, travel & hospitality"* Rhodes, Greece, 25–28 October 2018, 366–373
- Dreizis Y, Potashova I (2018) Yachting and coastal marine transport development in Black Sea coast of Russia. *Proceedings International Science Conference SPbWOSCE-2017 "Business Technologies for Sustainable Urban Development"*. <https://doi.org/10.1051/mateconf/201817005007>
- Elbeih SF, Elkafrawy SB, Attia W (2019) “Multi-criteria site selection and assessment of ports in the Northwestern Coast of Egypt: a remote sensing and GIS Approach.” *Int. J. Environ. Sci. Dev* 10(10):310–320. <https://doi.org/10.18178/ijesd.2019.10.10.1192>
- Feriol F, Vivet D, Watanabe Y (2020) A review of environmental context detection for navigation based on multiple sensors. *Sensors* 20(16):4532. <https://doi.org/10.3390/s20164532>
- Flynn S, Meaney W, Leadbetter AM, Fisher JP, Aonghusa CN (2021) Lessons from a marine spatial planning data management process for Ireland. *International Journal of Digital Earth* 14(2):139–157. <https://doi.org/10.1080/17538947.2020.1808720>
- Google Play (2020). <https://play.google.com/>
- Heßelbarth A, Medina D, Ziebold R, Sandler M, Hoppe M, Uhlemann M (2020) “Enabling assistance functions for the safe navigation of

- inland waterway”s. *IEEE Intell Transp Syst Mag* 12(3):123–135. <https://doi.org/10.1109/MITS.2020.2994103>
- Ioannidis SAK (2019) An overview of Yachting Tourism and its role in the development of coastal areas of Croatia. *Journal of Hospitality and Tourism* 1(1):30–43
- Kammler F, Kemmerich H, Brinker J, Thomas O (2019) Scrutinizing the design specifications of smart products: a practical evaluation in yachting. *Proceedings of the 27th European Conference on Information Systems (ECIS)*, Stockholm & Uppsala, Sweden, June 8–14.
- Kaup M (2010) Rola i znaczenie jachtingu w rozwoju polskiej turystyki wodnej. *Folia Pomeranae Universitatis Technologiae Stetinensis Oeconomica* 284(61):17–26
- Kulczyk S, Derek M, Woźniak E (2016) Zagospodarowanie turystyczne strefy brzegowej jezior na potrzeby żeglarstwa—przykład wielkich jezior mazurskich [Shore facilities for sailing - the example of Great Masurian Lakes]. *Prace i Studia Geograficzne* 61(3):27–49
- Luković, T (2012) Nautical tourism and its function in the economic development of Europe. In: Kasimoglu M. (ed.) *Visions for Global Tourism Industry—creating and sustaining competitive strategies*. InTech, Rijeka, Croatia. p. 399–428
- Łapko A (2018) Problems of yacht charter companies in Poland. *EJSM* 25:165–172. <https://doi.org/10.18276/ejms.2018.25-20>
- Łapko A, Lučić L (2019) The functioning of yacht charter companies in Croatia and Poland—a comparative perspective. *Res Papers Wrocław Univ Econ* 63(2):197–206. <https://doi.org/10.15611/pn.2019.2.17>
- Łapko A, Strulak-Wójcikiewicz R, Landowski M, Wieczorek R (2019) Management of waste collection from yachts and tall Ships from the perspective of sustainable water tourism. *Sustainability* 11(1):121. <https://doi.org/10.3390/su11010121>
- Łubczonek J, Trojanowski J, Włodarczyk-Sielicka M (2012) Zastosowanie trójwymiarowego zobrazowania informacji nawigacyjnej w mapach elektronicznych dla żegluga śródlądowej. *Archiwum Fotogrametrii i Kartografii i Teledetekcji* 23:261–269
- Mao X, Yang S, Liu Q, Tu J, Jaccard M (2012) Achieving CO2 emission reduction and the co-benefits of local air pollution abatement in the transportation sector of China. *Environ Sci Policy* 21:1–13. <https://doi.org/10.1016/j.envsci.2012.03.010>
- Migdał D, Hącia E (2019) The circulation of information in yacht ports. In *DIEM: Dubrovnik International Economic Meeting* 4(1):183–192
- Miler R, Bujak A (2012) Komercyjne systemy zobrazowania żegluga i aplikacje informatyczne transportu morskiego. *Logistyka* 3:1599–1609
- Nowacki M (2015) Turystyka żeglarska [Sailing tourism]. In: Stasiak A., Śledzińska J., Włodarczyk B. (eds.). *Wczoraj, dziś i jutro turystyki aktywnej i specjalistycznej*. Warszawa.
- Nur F, Marufuzzaman M, Puryear SM (2020) Optimizing inland waterway port management decisions considering water level fluctuations. *Comput Ind Eng* 140:106210. <https://doi.org/10.1016/j.cie.2019.106210>
- Payeras M, Marta J, Garica AM, Alemany M, Alcover A, Martínez-Ribes L (2011) “The Yachting Charter Tourism Swot: a basic analysis to design marketing strategies.” *Tourismos: An International Multidisciplinary Journal of Tourism* 6:111–134
- Polski rynek żeglarski (2016) Raport [Report on the Polish Sailing Market]. Polish Yachting Association. http://sailing.org.pl/polski_rynekzezlarski.pdf
- Popielarczyk D, Templin T (2014) Wykorzystanie technologii GIS do zwiększenia bezpieczeństwa transportu śródlądowego na Jeziorze Śniardwy. *Logistyka* 3:5259–5267
- Pranita D (2020) How digital capabilities can influence the co-creation of the yacht-tourism experience: a case study of Indonesia’s Marine Tourism Destinations. In *3rd International Conference on Vocational Higher Education (ICVHE 2018)*, p. 395–403. Atlantis Press.
- Santos N, Perna F (2018) Yachts passing by the west coast of Portugal—what to do to make the marina and the destination of Figueira da Foz a nautical tourism reference? *Pomorstvo* 32(2):182–190
- Sądecka D, Janusz M (2018) Legal basis of sailing development within 1989–2012. *Journal of Education, Health and Sport* 8(8):1255–1265. <https://doi.org/10.5281/zenodo.1469721>
- Sevinç F, Güzel T (2017) Sustainable yacht tourism practices. *Manag Mark* 15(1):61–76
- Strulak-Wójcikiewicz R, Łapko A, Hącia E, Wagner N (2019) Koncepcja utworzenia platformy internetowej dla portów jachtowych [The Concept of Creating the Internet Platform for Yacht Ports]. *Przedsiębiorczość i Zarządzanie* 20:337–349
- Strulak-Wójcikiewicz R, Wagner N, Łapko A, Hącia E (2020) Applying the business model canvas to design the E-platform for sailing tourism. *Procedia Computer Science* 176:1643–1651. <https://doi.org/10.1016/j.procs.2020.09.188>
- Valenta MT, Kijas. (2010) System wspomagania bezpieczeństwa żeglowania—integracja bazy danych, urządzeń mobilnych i transmisji bezprzewodowej. *Studia Informatica* 31(2B):90. https://doi.org/10.5072/SI2010_V31.N2B.420
- Wiktorowska-Jasik A, Tołkacz L (2013) Usługi logistyczne w jachtingu [Logistics Services in Yachting]. *Zeszyty Naukowe Problemy Transportu i Logistyki* 21:243–254
- Wang S, Yan R, Wu L, Yang D (2019) Optimal re-allocation of mooring areas for yachts. *Maritime Business Review* 4(1):94–105
- Wang YR, Zhang YK, Gu SY, Xu WF (2016) Research of the communication middleware of the yacht supervision management system based on DDS. *Proceedings 3rd Annual International Conference on Information Technology and Applications ITA 2016*, vol. 7
- Wiegman B, Witte P, Spit T (2015) Characteristics of European inland ports: a statistical analysis of inland waterway port development in Dutch municipalities. *Transportation Research Part a: Policy and Practice* 78:566–577. <https://doi.org/10.1016/j.tra.2015.07.004>