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Flexible Mobile Hub for E-Bike Sharing and Cruise Tourism: A Case Study

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Abstract: Bike sharing is no longer a novelty in transportation and has now become a mobility solution in its own right. This study investigated the potential scope of application of e-bike sharing solutions for a niche sector such as cruise tourism, the importance of which is growing, with the aim of improving sustainability and reducing pollution levels in cruise ports. A revealed preference survey was administered to cruise tourists, who chose a pilot e-bike service once they had disembarked from the ship to visit the nearby city center, to investigate the main variables affecting satisfaction with the service under investigation. An ordered probit model was specified and calibrated to identify the relationship among the variables influencing e-bike sharing usage by cruise tourists and their satisfaction. Subsequently, the marginal effect of each significant factor was evaluated to quantify its actual impact on the related e-bike sharing satisfaction level. The results obtained are consistent with the literature, but interesting interpretations are provided in terms of the relative importance of significant variables.

Keywords: e-bike sharing; transport sustainability; mobile depot; cruise tourism; ordered probit model

1. Introduction

In the last few years, bike sharing has become one of the most interesting and popular urban mobility options worldwide and, according to some authors [1–3], it is one of the fastest growing transportation solutions in the history of modern transportation. In 2014, the number of cities with bike sharing programs amounted to 855, with a total of 946,000 bikes operating worldwide [4]; at the end of 2018, according to Business Insider, these numbers had increased to 1600 and as much as 18 million, respectively. It is interesting to note that the number of bike sharing programs has doubled since 2014, whereas the number of bikes has increased by about 20 times in the same time span. In particular, a real boom has occurred in China over the last few years, making it the most important market in the world for this transportation mode at present. An example is the Hangzhou public bicycle program, launched in 2008 with 78,000 bicycles distributed among 2960 docking stations [5]. In particular, among the top 15 programs still active, the top 11 are located in China, followed by Paris, London, and Taipei; the Netherlands, as a whole, has the same fleet size as the Paris program (source: https://www.statista.com/chart/14542/bike-sharing-programs-worldwide/). Power-assisted electric bikes—better known as e-bikes—flourished in the early 2000s alongside traditional bikes and quickly gained great popularity. Electric bike sharing pilot projects have been proposed in many countries and by different actors (e.g., universities, port authorities, and municipalities). The positive aspects of e-bikes include the average higher speed allowed by the technology (up to 25 kph) and the reduced fatigue, favoring users such as the elderly/casual bikers and usage on uneven terrain in general. At the same time, capable batteries allow the extension of the potential average range of a trip [6]. However, e-bike components are costly and increase the vehicle weight, almost doubling it in comparison to traditional bikes. As far as the financial sustainability of the service is concerned, bike sharing is also a feasible business model for e-bikes, as the costs are spread over many users, in particular when integrated mobility is considered. The main themes of e-bike sharing concern them being hybrid vehicles, the relationship between range and demand, user interface and business model, and power supply management (recharging station, green power source, and duration). In this respect, it is interesting to note that pilot projects are increasingly proposing additional plug-in or removable batteries to allow the bikes to remain in service while the old battery is plugged in at the charging station.

The importance of Sustainable Urban Mobility Plans (SUMPs) and the widespread use of mobile devices to help users plan their trips, thus enhancing multimodality within local integrated transportation schemes, has resulted in bike sharing being considered a transportation alternative on its own.

Cycling has strategic importance for the sustainable development of cities and has become one of the fundamental parts of urban mobility strategies. The use of bikes as a transportation solution in urban and/or tourist contexts is universally recognized as positive due to the lack of polluting emissions, the reduction of traffic congestion, and the improvement of users' health. Bike sharing also provides a low-carbon solution to the "last mile" problem, playing an important role in bridging the gap among existing transportation networks, and is useful for recreation and tourism-related activities [7]. The presence of an effective bike sharing service can indeed make a city more attractive and easier to visit, strongly motivating tourists to choose it as a holiday destination. Bike trips can also become an integral part of the tourist experience, even when implemented to connect specific points of interest to the city center [8,9], with positive effects on its business model too. Despite that, every administration interested in introducing bike sharing programs for leisure/tourism purposes should take into account the many barriers that could hinder the growth and the development of this solution. The first element that users usually perceive as limiting is the lack of biking infrastructure, followed by the absence of knowledge about how to use bike sharing [10]. In general, all the system's elements need to be well designed in order to provide an efficient service capable of issuing basic but fundamental principles, such as autonomy, ease of utilization, user safety, and equipment security. Financial autonomy is, finally, the most critical goal. Many past projects in this field have failed or needed improvement mainly from the financial perspective [11]. The conflict between the necessity of offering low fares (in order to attract new users and guarantee an accessible public service) and the high overall costs of the service (due to vehicle and station maintenance, general operating costs, bike redistribution operations, etc.) may be solved, on the one hand, by a well-planned ad campaign or other forms of funding [12], and on the other hand, by developing strategies, infrastructures, and technologies capable of making the service more widely available (in particular, for tourism and leisure purposes), providing timely information for easy, satisfactory, and accessible use, even for short periods of time.

This paper sets out to examine two key research questions. First, what are the major driving forces for the development of e-bike sharing programs for cruise tourists? Second, what are the major motivating factors for cruise tourists to participate in e-bike sharing services?

In this study, these questions were investigated by means of a test case consisting of a prototypal container-based e-bike sharing mobile depot, located at the cruise terminal of Ravenna port—a small maritime town in Northern Italy—and by designing and implementing a methodological framework that included (i) a data collection and processing phase performed by means of a questionnaire survey administered to a group of e-bike users, (ii) the development of an ordered response model to identify the significant variables, and (iii) the evaluation of the marginal effects of the relevant outcomes.

The paper is structured as follows: In Section 2, an overview of the bike sharing system (BSS) evolution is provided and the suitability of the BSS applied to cruise tourism is investigated. The methodological framework is then introduced together with the statistical model. Section 3 outlines and discusses the principal results and findings. Concluding remarks on the test case are presented in Section 4.

2. Literature Review

2.1. The Evolution Framework of Bike Sharing

The variety of solutions related to bike sharing can be categorized according to target users (commuters, tourists, etc.), business models, vehicles, and project scale (municipal, regional, pilot, etc.). A broad classification of existing service categories splits the topic into (i) station-based systems, namely, the traditional bike sharing layout for public projects, with a relevant number of stations serving a high number of users for a vast area; (ii) free-floating systems, that is, the layout mostly adopted by private companies over the last few years, where bikes can be collected and dropped off anywhere within the service area by using technology devices for operation and payment; and (iii) bike rental, which is usually operated in tourist and leisure areas, with a single station and mainly during the peak season.

Bike sharing can be viewed as an evolution of bike rental in terms of target users (i.e., leisure mobility); on the other hand, bike sharing is based on the shared usage of a fleet of bicycles, available to users on a self-service, short-term, as-needed basis [12] and, in general terms, intended to be one-way from public spots, without bearing the costs and responsibilities of ownership. Bike stations are usually unattended; thus, users can manage all the different phases of the process (reservation, pick-up, and drop-off) on their own. The stations' network allows users to make point-to-point trips and return the vehicles to different stations. While bike rental can cover long periods, bike sharing is designed for short-term utilization; even the tariff scheme is designed for that purpose, with a certain amount of time granted for free (up to 30 min) and then a fixed fare issued for time unit [13]. Similar to car sharing, bike sharing programs normally cover purchase and maintenance costs, as well as storage and parking responsibility [14]. An important element that further underlines the difference between bike sharing and bike rental is the business model: BSSs can be classified according to their governing financing and managing model (e.g., public, private, or public–private partnership); ownership, operator, and operational model; scale; and range [15]. On the contrary, bike rental is almost always managed by a private owner and the benefits generated by the service (economic, environmental, and social) usually have a negligible effect on the urban community.

Despite the recent globally spreading trend of this transportation alternative, the first trials started in the late 1960s. In particular, five different generations in BSSs can be identified:

1. The "White bikes" project was introduced in Amsterdam, Netherlands in 1965. Bikes were made available free of charge at different locations across the city. Users could ride one bike to their destination and drop it off for the next following user [13]. The program came to an end in a few days, as bikes were either vandalized or appropriated for private use [16].
2. The second generation spread during the 1990s in Denmark and was replicated in many cities all over Europe and North America. In particular, the experiment called "Byciclen" in Copenhagen (1995) consisted of over 1100 vehicles, characterized by solid rubber tires and lenticular wheels located in docking stations throughout the city center and made available in exchange for a coin deposit which was refunded upon return. Despite this, the lack of a time limit for bike usage encouraged the practice of not returning the bikes to their stations.
3. During the third generation, "Smart Bikes" (or "IT-Based System") spread out, following the employment of technological improvements—such as electronically locking racks or bike locks, telecommunication systems, smartcards and fobs, mobile phone access, and on-board computers—which, as a whole, allowed for higher levels of security and the possibility to track the vehicles during the trips [12]. The most important third generation programs were launched in France (Lyon, La Rochelle, Paris, etc.) between 2005 and 2007, with significant results [13]. Apart from security issues, data on trips made it possible to survey users' habits both for research

and logistics purposes [17,18]; in particular, one of the main issues dealt with by contemporary research has been system rebalancing (i.e., relocating bicycles during the night from the destination spots to places where demand is stronger) [19–22].

4. The main innovations concerning the fourth generation have been the introduction of e-bikes and the integration of the service into public transit and car sharing schemes thanks to the use of smartcards, touch screen kiosks, and Global Positioning System (GPS).
5. The further acceleration in technological development and the return of free flow systems in place of docking stations started in China in 2016 and has paved the way for the fifth generation. Users can return the bicycles anywhere, resolving station availability issues, and the remote tracking of the locker and the use of mobile apps allow for precise and efficient collection/drop-off and payment systems.

Nowadays, the majority of active projects worldwide can be classified as either fourth or fifth generation, with docking stations and free flow models developing alongside each other.

2.2. Bike Sharing and Tourism

Since the 20th century, tourism has become one of the major sources of income for many cities. The relationship between tourism and transportation development is inseparable, and a balanced development of both of these aspects affects the local economy as well as nationwide and international competitiveness in many countries [7]. Socioeconomic factors influence transport mode choices for holiday travel. The size of the household or traveling with children, for example, have an impact on private car choice. In addition, a gap between environmental consciousness and travel choice is observable for holiday mobility [23]. Bike tourism can be split between cycle holidays, where cycling is the main purpose (usually in rural or natural regions), and holiday cycling, in which the occasional use of a bicycle is chosen as an alternative mode of transportation for exploring a destination [7]. A simple definition of bike tourism has been proposed, among others, by Han et al. [24]:

- users are away from home;
- the duration of the trip can vary from a single day to several days;
- noncompetitive means of transport;
- recreation/leisure form;
- cycling should be the main purpose of the holiday;
- occurs in an active context.

However, bicycle tourism has remained a marginal niche until the last decade. Indeed, at the end of the 1990s, cycle tourism was estimated to represent around 2–4% of total holidays. Nowadays, this share is rapidly growing, especially in countries characterized by a strong bike-oriented tradition, such as Scandinavian countries. Biking has become the preferred leisure activity of many other groups of people because it makes it possible to enjoy authentic experiences connected with nature and culture that would not be available traveling by car [25].

A bike rental system for tourists traveling by train, coach, underground, and trams would allow for renting and returning bikes close to tourist attractions and main transport routes, which in turn need to be marked and equipped with information facilities to ensure that tourists have a smooth experience in any condition, even without specific skills or proficiency [26]. Increasing numbers of case studies document the success of collaborations between bike clubs/communities, land managers, as well as government and tourism organizations in the design, construction, and maintenance of tracks, larger-scale facilities, opportunities, and data sharing [27].

Contemplation, exploration, stimulus seeking, self-development, physical challenge, and social interaction are the main motivators for tourist cycling. Beyond the wide heterogeneity among bike sharing users in terms of gender, age, and education background, tourists' motivations and needs have to be taken into account from the earliest phases of the decision-making and promotion processes in order to drive the formation of a positively perceived value of bike activities, resulting in satisfaction, desire, and loyalty. Otherwise, factors such as fatigue, misunderstanding of the rules, and knowledge gaps may result in foreign tourists perceiving barriers to hiring a means of transport abroad [7]. Evidence provided by European project reports, press articles, and, to a minor extent, scientific literature demonstrate that e-bikes are used when available, although less usually than traditional bikes. Indeed, e-bike preference is common among those attracted by the technological aspects. Therefore, Cairns et al. [28] conclude that new BSSs should rely preferably on manual bikes that can be easily upgraded to electric in a second step.

From the market side, BSSs have had, as a whole, varying degrees of success. Proper strategies need to integrate transport planning, system design, and choice of business model to develop a system of products and services capable of fulfilling users' needs, and this is even truer for services addressing tourists. A sustainable bike sharing system cannot be split from supportive local policies, infrastructure, assessment of users' motivations, and close cooperation with private stakeholders and developers [29]. Beyond the positive aspects, BSSs, according to de Chardon [30], have failed in (i) fighting social exclusion; (ii) providing a feasible transport alternative due to the reduced size of the fleet; (iii) being transparent as far as purposes, benefits, economic sustainability, and success metrics are concerned; and (iv) building a comprehensive integrated transport plan towards sustainability. In addition, the technological aspects have been unnecessarily stressed to attract investment and advertising rather than complying with mobility topics.

2.3. Bike Sharing and Cruise Tourism

A cruise could generally be defined as a voyage on a ship undertaken wholly for reasons of leisure and recreation [31]. Many private companies (cruise companies) organize trips usually starting from North America, Europe, or China with a variety of different destinations all over the world. Caribbean and Mediterranean cities account for as much as 55% of cruise capacity [32]. Nowadays, this sector is recognized by many authors as one of the most dynamic from the points of view of both maritime transportation activities and tourism. Just to mention some figures, in 2011, around 20 million cruise passengers were counted, with an annual growth rate of around 7% [33]. In parallel, the number and dimensions of ships have also dramatically increased. Currently, the biggest ships are able to carry as many as 6000 passengers [34]. The supply of cruise products has also become more diversified. On one side of the spectrum, there are small-scale adventures or luxury cruises to the most remote and vulnerable marine environments; on the other hand, there are large-scale cruises on vessels equivalent to floating cities that operate to established cruise destinations, such as the Caribbean, the Mediterranean, and Northwest Europe. Other activities (i.e., river cruising and boating) have also gained popularity in several regions. This industry is surely facilitating an improvement in the tourism potential, infrastructure, and social development of a large number of port cities, but it is also producing a negative impact on maritime, urban, socioeconomic, and environmental resources. In fact, in addition to the general global impacts produced by the cruise industry (GHG emissions, water pollution, waste production, etc.), many local effects produced by the arrival of big ships in fragile contexts or small seaside locations have to be considered. Typically, cruises foresee frequent intermediate stops at locations in which tourists can spend only a few hours visiting the place and doing shopping. Many authors [31,32,35] demonstrated that the benefits derived from this kind of tourism, hospitality, and transportation model are usually marginal compared with the social costs generated, which can be up to seven times larger. Thus, it is very important to develop sustainable solutions in order to mitigate the strong impact generated by the arrival of many cruises at seaside locations, with particular reference to the transfer mode from the ship to the city center or other tourist attractions. Traditionally, trolleybuses or other motorized vehicles have been used for this purpose. Offering alternative transportation services—bikes, for example—could be an interesting but challenging solution.

The sustainable behavior of many cruise-goers is challenged by the low familiarity with the place and the reduced comfort of the displacement. In fact, bike sharing seems to be one of the most promising measures to encourage people to choose sustainable means of transportation during their holidays, especially in urban contexts. In particular, tourists seem to appreciate the possibility to use a healthy, enjoyable, and relatively cheap door-to-door transportation mode at the holiday destination. These effects are maximized in cities with a good level of infrastructure, such as segregated bike paths and routes with low traffic volumes dedicated to leisure activities. A study carried out in Copenhagen [7] demonstrated that 67% of the persons interviewed had visited a cycling-friendly city at least once or twice in their life. In the same study, the authors found that cycling was enjoyed both by people coming from cycling-oriented countries (that may use it as a habit) and those from noncycling countries (to whom the possibility to experience a new transport solution was proposed).

Thus, we can say that an efficient bike sharing system is one of the most requested and valued services by travelers nowadays. Considering this, tourists using bike sharing could enhance both the financial and environmental performances of the service, helping to reach a positive revenue/expense ratio [15], while at the same time reducing the negative footprint on urban and natural environments introduced by tourism (i.e., pollution, congestion rates, etc.), which will in turn increase cities' livability and attractiveness in a positive loop.

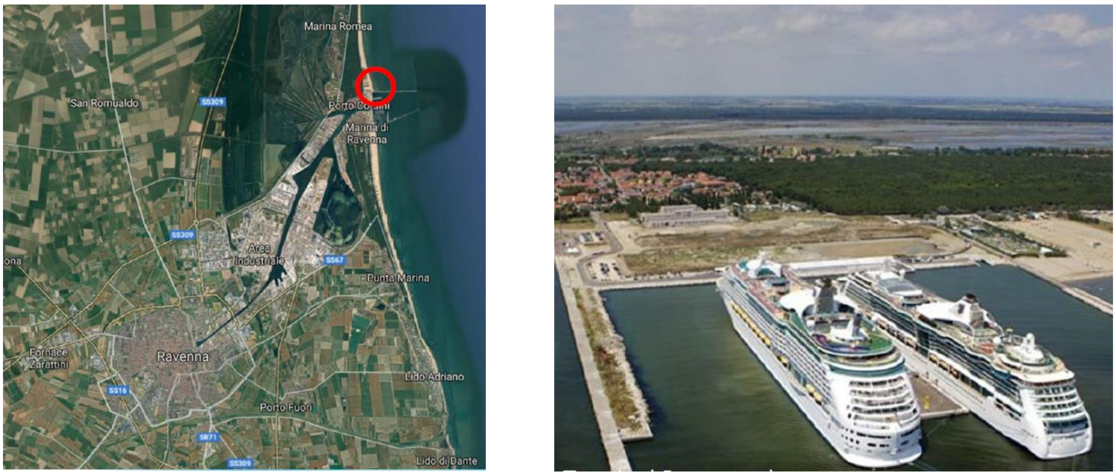
Even if the literature has so far focused only on behavioral aspects [24] and sustainable mobility features connected with bike sharing, its feasibility for tourist purposes has been explored by means of pilot projects. A pilot project carried out by the Valencia port authority in close cooperation with the municipality relied on both the tourist vocation and the good level of maritime infrastructure of the city. The mobile automated bike depot proposed allowed reaching the city center (6.5 km from the port) by means of 10 electric bikes with an easy and sustainable mobility solution. The project was jointly financed by Valencia port and the European Community and operated for a six-month test period. The service was tailored to younger people and dynamic adults; bikes were made available by means of a dedicated app at the port and a temporary drop-off point in the city center. The e-bikes were equipped with a smart GPS locker system and batteries, the recharge point of which was powered by solar panels. The weak points of this project were the high running costs needed outside the European Community's funds and the limited scope for action, where the advertising campaign and local stakeholder commitment were thwarted by packages offered onboard by cruise companies. The main lesson learned from this project is the paramount importance of commitment from both local stakeholders and cruise companies to make the service attractive and economically consistent.

"Quikbyke" is a 2015 spin-off of a renowned producer of e-bikes with the purpose to promoting their use in tourist locations by means of a solar-powered rental point (called "shop-in-a-box"), which could be quickly removed and transported to another location in order to satisfy the seasonal travelers' flows. The first trials were installed in Omaha, Nebraska, United States during summer 2016 and moved during winter to St. Petersburg, Florida, United States to attract the winter cruise passengers. The fully solar-powered rental point can be run while recharging up to six e-bikes at the same time, with no external energy inputs. The standard size and self-contained design of the box makes the handling easy by ship or truck (the latter solution was also adopted in our test case). Vehicles are equipped with lithium-ion batteries that allow a 40–50 km range. Even if the fares were quite high ($5 for 30 min) in comparison with the Valencia and Ravenna test cases, the project proved itself so successful that the owner is planning to expand through franchising in the Caribbean area, where many cruise companies operate and better environmental conditions exist.

3. Materials and Methods

3.1. Case Study: An E-Bike Sharing Service with a Mobile Hub

The motivation that led to the development of this test case is to increase the attractiveness of the port of Ravenna and its hinterland by fostering an efficient, on-demand transport system, guaranteeing, at the same time, sustainable connections between the cruise passenger terminal and the historical city center. The bike depot analyzed in this paper is a tentative solution which mixes together the positive aspects of each of the three categories mentioned above in order to be accessible and attractive for tourists and tourist locations (where seasonal and discontinuous tourist flows exist), providing user friendliness and the possibility of being easily transported according to the spatial and temporal demand pattern Figure 1.



(**a**) (**b**)

Figure 1. (**a**) Ravenna Corsini port area and city aerial view. (**b**) Port basin and quays of Ravenna Corsini port.

The Ravenna cruise terminal is a 20 min drive from the Ravenna city center (12 km). Nowadays, tourists reach the city center mainly by shuttle services organized by cruise companies. Independent travelers can reach the city center by public transport (bus service), but the stop location is not favorable. The classic bike sharing schemes are not appropriate for developing a service suitable for cruise passengers. In fact, the concentration and variability of demand (both in terms of volume and time), the need to have pick-up and delivery stations close to the ships, and the need for coordination between the service manager and the cruise company have led to the development of a prototypal bike sharing service with a "mobile hub", that is, a service capable of being transported wherever necessary and only when necessary. The Ravenna case study, described in this work, was developed and financed in the framework of the "Moses" Standard + project (Maritime and multimOdal transport Services based on Ea Sea-Way project) financed by the Italy–Croatia CBC Program 2014–2020 and based on the main results of the IPA Adriatic project EA SEA-WAY. The Moses project's objective is to improve the accessibility and mobility of passengers across the Adriatic area and its hinterland through the development of new cross-border, sustainable, and integrated transport services and the improvement of physical infrastructures related to those new services.

The mobile hub depot in Ravenna port was tested in summer 2018. The 20 ft equivalent mobile depot was advertised on-site and could shelter as many as 20 e-bikes (including 1 tricycle tailored to address disabled users' needs), the charging points, and the complementary items of each vehicle (helmets, GPS tracker tools compatible with Google maps and a data storage unit, lithium-ion batteries, and security locks). The bikes had a declared range of up to 50 km, an electric engine on the front wheel, and an integrated shift on the back wheel. While the bikes weighed as much as 20 kg, the tricycle weighed as much as 30 kg. Moreover, the declared recharge time of the batteries was 6 h Figure 2.

Figure 2. Mobile depot for e-bikes at Ravenna port.

3.2. Conceptual Framework and Data Collection

A conceptual framework (data collection, data processing and modeling, and outcome) was proposed in order to explore and analyze the factors influencing the degree of satisfaction connected to the use of e-bike sharing services, as shown in Figure 3. The relationship between service and customer satisfaction has been explored widely in the literature. For example, Pruyn & Smidts [36] studied the negative effect of waiting time, Gallarza & Gil Saurab [37] explored the existence of a "quality–value–satisfaction–loyalty" chain, and De Vos [38] concluded that users traveling with their preferred mode are more satisfied—other things being equal—than those who, in addition, overperceive travel time. The inputs of the model were the potential explanatory variables and the degree of satisfaction. A Revealed Preference (RP) questionnaire was designed and issued to users when returning the bike in order to collect users' characteristics, bike sharing usage, and satisfaction data. The explanatory variables were grouped into individual characteristics (age, gender, and role on board—i.e., passenger or crew member), trip-related factors (use of other public transport modes in the same trip, duration, and travel purpose—i.e., destination being the historical city center or beaches), and personal perception (ease of use, familiarity, reliability, and willingness to pay (WTP)).

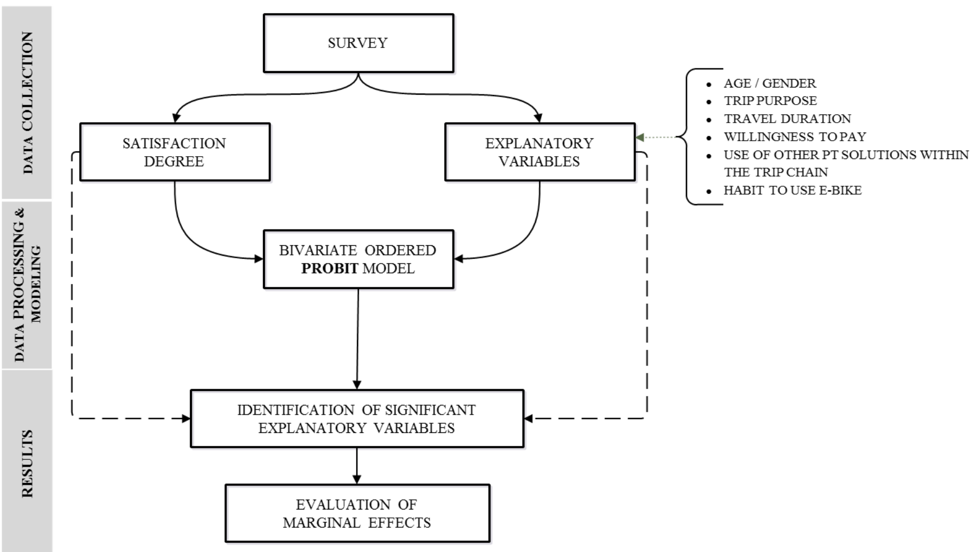


Figure 3. Methodological approach of the survey and data analysis.

As previously described, the main aim of this study was to identify which explanatory variables (individual, travel-related, or perceptual) are significant and their relationship with the satisfaction degree and attractiveness of the examined service. An ordered probit model was developed to identify the variables influencing e-bike sharing usage by cruise tourists and their satisfaction.

The total sample surveyed consists of 120 cruise passengers and crew members of cruise ships moored in the Ravenna cruise terminal in October 2018. The cruise traffic at Ravenna port along the pilot project duration had been harmed by meteorological conditions, so that three out of the eight ships foreseen did not manage to enter the port. This greatly limited the sample size. Two other constraining factors were the reduced extension of the available e-bike fleet (20 vehicles) and the all-inclusive feature of the travel packages bought by cruise-goers, which discouraged the use of services on the spot. The members of the sample were individual travelers from all over the world, of different ages, travel behaviors, and social backgrounds, who stopped only for a few hours to visit the historic center of Ravenna, the beaches, or other tourist attractions.

Special attention was devoted to designing the survey in order to provide comprehensible, easy-to-understand, and easy-to-answer questions, while at the same time ensuring sufficient information would be collected and a reduced nonresponse ratio. It is important to underline that variables widely used in literature on bike sharing surveys were considered here (e.g., trip duration, user friendliness, ease of pick-up/return, etc.). In addition, an estimate of the willingness to pay has been provided, which is, to the best of the authors' knowledge, a key aspect not frequently dealt with in the existing literature.

Table 1 summarizes the variables considered. The bike sharing satisfaction degree was defined as a typical ordinal variable scaled according to a 3-point Likert scale: 0—Bad, 1—Average, and 2—Good. Cronbach's alpha was used as a criterion to measure the reliability of the questionnaire; the result ($\alpha = 0.719$) showed a sufficient level of consistency of the data.

Table 1. Summary statistics for ordered observed variables.

Variable	Description	Value	Frequency (%)
Age group	<30	0	25%
	30–50	1	43%
	>50	2	32%
Gender	Male	1	59%
	Female	0	41%
Pax/Crew	Passenger	1	70%
	Crew staff	0	30%
Trip duration	<1 h	0	28%
	1–3 h	1	36%
	>3 h	2	36%
Destination	Historic center	1	58%
	Beaches	0	42%
Willingness to pay (WTP)	<€10/day	0	31%
	€10–20/day	1	57%
	>€20/day	2	12%
User friendliness and ease of pickup/return	Yes	1	84%
	No	0	16%
Other Public Transport utilization	Yes	1	59%
	No	0	41%
First time e-bike	Yes	1	61%
	No	0	39%
Satisfaction	Bad	0	19%
	Normal	1	35%
	Good	2	46%

3.3. Statistical Model

Discrete outcome modeling techniques are frequently utilized, as the dependent variables consist of categorical or ordered variables. When treating such variables, general statistical models, such as least-squares (LS) regression, suffer from many shortcomings, such as heteroscedasticity, violation of assumption of independence, identically distributed errors, and predicted probabilities outside the unit interval. Even basic statistical analysis, such as ANOVA or the *t*-test, are unreliable because the key assumptions of these models are that the response or dependent variables must be continuous, with normally or roughly normally distributed residuals. A wide body of literature recognizes that linear regression is inappropriate when the dependent variable is categorical or ordered, as in our specific case. An appropriate theoretical model in such a situation is the ordered probit model [39].

Following these premises, an ordered probit model was developed and calibrated to identify factors that potentially affected the satisfaction degree of e-bike sharing with the mobile hub for the cruise tourists. In ordered models, an ordered dependent variable is explained by a number of scaled independent variables and the parameters of the latent model do not have a simple interpretation per se. Rather, the main interest lies in the shift of the predicted discrete ordered outcome distribution as one or more of the regressors change (i.e., the marginal probability effects).

In our particular case, by adopting this approach, we could account for the commonly shared unobserved factors that affect both e-bike sharing usage by cruise tourists and the related satisfaction degree. Subsequently, the marginal effects of each determined factor (significant variables) were evaluated to quantify their actual impacts on the related e-bike sharing satisfaction levels.

Originally developed in biostatistics [40], this model was brought into the social sciences in the 1970s, and recently, it has been widely applied in transportation studies. In greater detail, several applications can be found in vehicle ownership analysis [41], road safety and injury models [42,43], determinants of bicycle choice [44], cyclists' travel behavior [45], and car sharing usage [46].

The model was defined and specified starting from the ordinal data observed for each observation, under the hypothesis that a latent continuous metric driving the ordered responses given by the users existed. The model is expressed with the following well-known form:

$$y_i^* = \boldsymbol{\beta}_i \boldsymbol{X}_i + \varepsilon_i, \quad y_i = k \; if \;\; \mu_{k-1} < \; y_i^* < \; \mu_k, \quad k = 0, \ldots, K \tag{1}$$

where y^*_i is the latent, unobserved dependent variable (satisfaction degree); $\boldsymbol{X}_\mathrm{i}$ is the vector containing the independent (measured) variables; and $\boldsymbol{\beta}_\mathrm{i}$ is the vector of unknown regression coefficients associated with the explanatory variables. While it is not possible to observe the true values of the y^*_i variables, it is instead possible to observe the actual ordinal answers y_i provided by users on the 1,2,3 scale within the thresholds μ_k.

As usual, ε represents the random error term, normally distributed with mean = 0 and variance = 1, $\varepsilon_\mathrm{i} \sim \mathrm{N}(0,1)$. Under these hypotheses, the probability of observing each ordinal response is given by

$$\begin{aligned} P[y_i = 1] &= P\Big[\mu_0 < y_i^* < \mu_1\Big] = P[\mu_0 < \boldsymbol{X}_i\boldsymbol{\beta}_i + \epsilon_i < \mu_1] \\ &= P[\mu_0 - \boldsymbol{X}_i\boldsymbol{\beta}_i < \epsilon_i < \mu_1 - \boldsymbol{X}_i\boldsymbol{\beta}_i] = \Phi(\mu_1 - \boldsymbol{X}_i\boldsymbol{\beta}_i) - \Phi(\mu_0 - \boldsymbol{X}_i\boldsymbol{\beta}_i) \end{aligned} \tag{2}$$

where $\Phi(\cdot)$ is the standard bivariate normal cumulative distribution function. It is straightforward to see that, in general terms,

$$P[y_i = k] = \Phi(\mu_k - \boldsymbol{X}_i\boldsymbol{\beta}_i) - \Phi(\mu_{k-1} - \boldsymbol{X}_i\boldsymbol{\beta}_i). \tag{3}$$

The unknown parameters in the model—the coefficients vector $\boldsymbol{\beta}_{\mathrm{i}}$—were estimated by means of the Maximum Likelihood Estimation (MLE) technique, maximizing the log-likelihood function:

$$lnL = \sum_{i=1}^{N}\sum_{k=1}^{K}\delta_{ik}ln\Big[\Phi_{i,k} - \Phi_{i,k-1}\Big] \quad (4)$$

where $i = 1, \ldots, N$ is the sample size, $\Phi_{i,k} = \Phi[\mu_k - \mathbf{X}_i\boldsymbol{\beta}_i]$, and $\Phi_{i,k-1} = \Phi[\mu_{k-1} - \mathbf{X}_i\boldsymbol{\beta}_i]$. The estimated coefficients do not allow for immediately quantifying the magnitude of the related explanatory variable effects on the satisfaction but only for evaluating the direction (positive or negative) of the effects on the outcomes. To properly quantify the impacts, the marginal effects of each explanatory variable of interest were calculated as follows:

$$\frac{\partial P(y_i = k)}{\partial \mathbf{X}_i} = [\phi(\mu_{k-1} - \mathbf{X}_i\boldsymbol{\beta}_i) - \phi(\mu_k - \mathbf{X}_i\boldsymbol{\beta}_i)]\boldsymbol{\beta}_i \quad (5)$$

where Φ is the probability density function of the standard normal distribution.

4. Results and Discussion

Following the methodological framework reported in Figure 3, the calibration of the binary ordered probit model allowed us to identify the significant variables and to estimate the marginal effects, that is, the variations of satisfaction level as the regressors change. The results of the calibration are reported in Table 2. Only the variables that were significant (p-value < 0.05) were included in the model.

Prior to discussing the results, it is useful to repeat that this was an initial exploratory analysis carried out during a short pilot project and, thus, the results must be treated with caution, given the dimension of the sample available. The scientific literature on surveys suggests a relationship between the dimension of the sample, population size, desired degree of accuracy, and confidence interval [47]. It is worth noting that, at the time of analysis, the service analyzed was extremely niche although promising; thus, in the authors' opinion, the identification of the attributes that appear to significantly influence travel behavior is still useful from a policy point of view. In addition, the results obtained are consistent with the literature on bike mobility and contribute to shedding light on a rather unexplored research topic. A relevant ratio of users accepting to answer the survey is, other considerations notwithstanding, a significant result for the research scope and justified a reduction in the sample size [47].

Eight significant variables were identified (p-value < 0.05); the magnitude and the sign of the calibrated parameters provide a general evaluation of the impact on the satisfaction level. This analysis was helpful to answer the first research question: What are the major factors acting as drivers for the development of e-bike sharing programs for cruise tourists?

Table 2. Results of the model.

Variable	β	Std. Error	p-Value	Marginal Effect
Age (>50)	0.255	0.097	0.018	0.0671
Passenger	0.106	0.112	0.007	0.0344
User-friendliness and ease of pickup/return	0.548	0.156	0.000	0.1415
Trip duration (>3 h)	0.379	0.174	0.000	0.0826
Destination center	0.504	0.064	0.002	0.1106
WTP (€10–20/day)	0.211	0.104	0.023	0.0508
Other public transport utilization	-0.132	0.080	0.006	-0.0398
First time e-bike	0.444	0.156	0.000	0.0979
Log-likelihood at convergence	−1987.35			
Likelihood ratio index (ρ^2)	0.194			

All the significant variables—except the one related to utilization of other public transport services in the same trip chain—had a positive effect on the satisfaction level.

The estimation of the marginal effects, on the other hand, answered the second research question: What are the major motivators for tourists to join a bike sharing service? In fact, the magnitude of users' satisfaction variation with each parameter allowed us to determine the key aspects to focus on to promote a more efficient and popular service. In detail, e-bike users over 50 years of age showed a positive marginal effect on satisfaction level of around 7%, and this is in line with the evidences available in the literature [48,49]. Concerning trip duration, average usage of >3 h had a higher impact on satisfaction (+8%). In the literature, we found much lower average values for the duration of e-bike trips (as much as 30 min) [6,50,51]; therefore, we assume that satisfaction was linked here to longer trip duration mainly due to the specific case (trip purpose and users' characteristics).

Concerning the WTP, according to the results, a service fare in the range of €10–20 per day had a significant positive effect on satisfaction and an estimated marginal utility of around 5%. This is roughly consistent with average fare values found in the literature, although the average journey time found here may imply higher costs [52–55]

Even the "first-time users" involved in the analysis perceived the service positively (almost +10% marginal effect). This is probably linked to the positive feedback regarding the user friendliness of the e-bike and the innovativeness of the pick-up and delivery solution based on a mobile hub station. In addition to that, the marginal effect on the degree of satisfaction generated by the ease of use was the highest among the significant variables inspected (+14%).

Users also showed a greater propensity to use the e-bike sharing service to reach and visit the historic city center (see Table 1), with an intrinsic marginal effect on satisfaction of +11%.

Interestingly, the use of other public transport modes in the same trip chain showed a marginal drop in satisfaction (−4%), probably due to the lack of integration between the different services in terms of connections, frequencies, and fares; also, this finding is in line with the existing literature [56–58]. On the other hand, the use of integrated multimodal fare schemes is reported in the literature as being a driver of paramount importance for the use of public transport systems by tourists, along with the degree of integration and flexibility of transport systems [59].

5. Conclusions

Over time, bike sharing has come to represent a successful story of sustainable transportation opportunities, the diffusion of which is also relevant and indisputable in those countries which have been so far less sensitive towards environmental concerns [60]. The aim of this paper was to propose and assess the opportunities for an additional niche of operation for e-bike services consisting of a mobile depot which can be easily moved and transported within and across both port and urban areas to respond to demand evolution. Two research issues were proposed: the identification of (i) the major factors driving the development of e-bike sharing programs for cruise tourists, and (ii) the main motivators for cruise tourists to join a service of this kind.

As activities during cruises are usually thoroughly scheduled by the ship owner, the scope of the solution described in this paper is limited only to cases where a partnership/sponsorship exists between local stakeholders, cruise promoters, and technology suppliers or where a limited and floating demand exists, such as in marinas. Under these premises and from a managerial point of view, the main aspects foreseen to make the service effective are the infrastructure (paths and, foremost, a user-friendly collection/drop-off system that is easy to use even for first-time users), transport integration and tailored fare schemes in order to fight segregation of certain users' categories, and a focus on safety and reliability (i.e., information provision, ad campaigns, comfort, and design of docking stations).

The survey conducted during the pilot project in Ravenna involved a diversified sample of users of different ages and nationalities/countries of origin. The use ratio of the service was quite low compared to the population of a typical cruise vessel, but the response ratio was high, since almost all users agreed to answer the survey when returning the vehicle. The statistical analysis showed good satisfaction among users, even when they were not familiar with e-vehicles, which is traditionally perceived as a barrier in the mainstream literature on the topic [61]. The results obtained by the calibration of the binary ordered probit model are consistent with the literature. The promising aspects of this work lie in the recognition of a new niche of application of shared mobility that goes beyond the traditional boundaries of users' average age and WTP, as well as the distance and time traveled threshold usually connected with bike sharing, which can be ascribed to the peculiar vocation of the service. Users appreciated electric-powered vehicles for traversing the surroundings of the port, even when they were not familiar with such vehicles.

This conclusion has a potentially significant scope of application at the policy level, steering the municipality and the stakeholders to foster sustainable transportation schemes linking the port and the city center, notwithstanding the distance. A tailored and effective business model is needed to run this service, and transport integration can be a solution (together with schedule coordination to reduce transfer time loss, which greatly affects users' appreciation). Finally, additional progress on the safety and reliability of the service can be achieved with close cooperation between the local administration and the bike vendor.

Further research may set out to investigate fleet management and technology, which can improve appreciation and feasibility. For example, GPS tracking costs increase with precision requirements; nevertheless, the analysis of GPS tracking data is useful for public administration and transport agencies to map users' travel behavior and paths and thus to design supply opportunities accordingly.

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