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Innovative electric bike-sharing services for the promotion of sustainable connections among small touristic ports and inland: the Ravenna port case study

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1 Introduction

Tourism is one of the main income sources for countries and even more for local areas. Mobility-related issues have thus started to become apparent, mainly in small and delicate areas such as cruise ports and marinas where highly variable demand due to touristic flows makes it difficult the provision of sustainable and reliable transportation connections with the inland areas.

Bike sharing systems have been proposed by municipalities as sustainable transportation solutions. On the other hand, a crescent awareness towards sustainable tourism is traceable also among travelers, which value bike sharing for tourism trips under determinate conditions.

The paper presents a robust review on issues and solutions proposed to face transportation topics on similar contexts. A special focus is then provided to a pilot test case conducted in the city of Ravenna, Northern Italy during the 2018, in the framework of the Interreg Italy-Croatia project *Moses*. The potential of an innovative and flexible electric bike-sharing service supported by the use of a Mobile Depot, where bicycles are stored, charged and undergo maintenance is presented.

Unlike traditional fixed station and modern free floating bike sharing systems as well as rent-a-bike services, the flexibility of the solution proposed consists in the possibility of moving the mobile depot (a 40-feet container specifically re-arranged to fill the scope) and the bicycles therein stored between target location and places, according to the schedule and itinerary of the cruisers. GPS data on bike utilization and paths collected during the pilot, as well as the result of a survey issued to users, are analyzed to highlight the values and appealing factors of this service even for medium distance trips (up to 30 km round trip) covered between the Ravenna cruise terminal and the historical city center.

Transferability of the pilot will be inspected by proposing a business model showing the economic and technical convenience of electric bike sharing and related services to provide intermodal, low cost and reliable sustainable transportation solutions connecting port areas with the city centers for independent cruisers and crew members. In the authors' perspective, the flexible and low-cost solution proposed (i) balances the strength points of established cycle-based systems, (ii) addresses the seasonality issue connected to touristic flows and (iii) fills the gap in the scientific literature on the niche topic of sustainable and affordable mobility solutions for touristic ports and marinas.

> In the authors' perspective, the flexible and low-cost electric bike sharing service developed in the Interreg Italy-Croatia Moses project (i) balances the strength points of established cycle-based systems, (ii) addresses the seasonality issue connected to touristic flows and (iii) fills the gap in the scientific literature on the niche topic of sustainable and affordable mobility solutions for touristic ports and marinas.

2 The bike sharing framework

Bike sharing has become over time a standalone modal alternative as far as mobility is concerned thanks to features such as free-flow access, self-service and the possibility of performing one-way trips without returning the bike to the origin station. Part of its fortune is linked to integrated transportation schemes and to the crescent use of mobile tools to help users to plan their trip, thus enhancing multimodality. Finally, also tariff schemes encourage its use on an as-needed basis (Shaneen et al., 2010; Bakogiannis et al., 2018; Si et al., 2019).

Although born in Europe (Amsterdam, 1965) bike sharing programs spread worldwide: in 2014, 855 cities were involved with a total of 946,000 bikes operating while at the end of 2018 the number of programs had doubled, and the number of bikes was around 20 times larger. The large majority of programs with regard to fleet size are now located in far-eastern countries such as China.

By learning from failures the systems evolved by gradually replacing characteristics such as coin-deposit system and docking stations with electronic locks, user-friendly interface (for example by means of mobile phone or smartcards), dock-less (free-flow) systems, e-bikes and GPS tracking which allow communication between on-board computer, the provider and/or the users' devices. For example, the mobile app developed by "Mobike" (www.mobike.com/it) allows to locate the bikes, unlock them by scanning a QR code and when the locker is toggled at destination the corresponding amount of money is deducted from the user's account balance. Apart from security issues, data on trips made it possible the survey of users' habits both for research and logistic purposes.

The presence of an effective bike sharing service can serve as an improvement towards making cities more attractive and easier to visit also for tourists, which on vacation are less caring towards sustainable behavior than when they are at home. Packages and experience tours have been developed by city administrations, local entrepreneurs, tourist offices or guide tours providers, with bike experience as one of the main features to connect points of interest to city centers along bikeable routes (Bakogiannis et al., 2016; Musolino et al., 2019). The introduction of e-bike and pedal-assisted vehicles has encouraged the diffusion of such practices and solutions.

A service gap which has not yet been explored in depth is the provision of sustainable or electric means of transport from the ports and marinas to the principal urban centres. One of the main issues to address before implementation is the relationship between how the service is designed and the input demand profile (i.e. ship and/or boats hosting tourists and staff, who are potential users of the tailored service) which is not stable over time and in size due to the intrinsic seasonality of tourism flows. The topic of the relationship between ship flows and port and marinas is hard news both in terms of safety and environmental sustainability.

There are two types of electric-assisted configurations: pedal-assist and throttle assist. In the former case the motor only assists the user while pedaling, while throttle assist is more similar to a motorcycle and it's legal primarily in the United States. Hybrid systems combine the two. The *pedelec* in Europe is legally classified as a bicycle as the maximum speed is below 25 km/h. It is considerably heavier than an ordinary bike because of the technology tools included and is hard to pedal when the battery is switched off or flat. Giving the sensation of cycling with a tail wind or slightly downhill, the e-bike is quicker, it enables longer trips over hilly routes, and it is an alternative for people who, for various reasons, are averse to bicycling. Compared to local public transport and rush-hour driving, the e-bike offers competitive travel speeds. Thus, it has the potential to be a substitute for car and public transport trips. Sales figures indicate that the earliest adopters of e-bikes have been the elderly. A study carried out in Norway by Fyhri and Fearnley (2015) showed that e-bikes increased both number of trips and average distance cycled for all trip purposes, in particular for females which usually travel less frequently and for shorter distances (Krizek et al., 2005). In addition, the analysis suggests a clear learning effect, i.e. the longer the test period, the more the bicycle were used confirming the findings of Shao et al. (2012).

E-bikes experimented a nebulous legal lane at the beginning, with some authorities considering them equal to motor vehicles while others don't. A study conducted by Cherry and Cervero (2007) in China pointed out differences in judgement among policy makers at urban level, on varying the transport solution to which e-bikes act as a substitute (i.e. a shift from taxi and private mobility to e-bikes is more welcome than a shift from traditional to e-bike from the environmental sustainability point of view). E-bikes allowed several and longer trips compared to traditional bikes, thus requiring a larger amount of energy to power supply. From the regulation point of view, the opportunity of sharing bike lanes with traditional bike or vehicle lanes can have an impact on safety and travel time. Campbell et al. (2016) explored users' attitudes in Beijing, which is one of the cities hosting the largest number of e-bikes worldwide, towards factors such as distance, air quality, weather and competing/substitute travel alternative. Cairns et al (2017) and Li et al. (2018) investigated the same aspects at the European level, with a particular reference to London area. As far as Italy is concerned, bike utilization rate is growing slowly but constantly in both medium and large cities, with public-led bike sharing programs playing an important role in enhancing bike use in contexts deeply relying on private car transport. During 2017, some private operators introduced free-floating systems and e-vehicles, making the available fleet double in a very short time.

Researchers need to upgrade knowledge on users' attitudes in order to provide timely and relevant information to policy makers to guide transportation decisions along a sustainable path.

3 Review of present and past experiences of innovative and sustainable intermodal transport solutions in port areas

The relationship between tourism and transportation is stronger than it seems and a balanced development of both is a positive target for the economy. The sector of cruise tourism is growing at a steady pace (Di Vaio and Penco, 2013), bringing in concentrated peaks of traffic, safety issues in fragile contexts (see the recent missed collisions during 2019 in Venice for example) and environmental decline. Sustainable transport solutions for passengers during stop-over – other than trolleybus and motorized vehicles - are paramount to reduce the externalities. In addition to that, ports for large ships are sided by a larger number of small marinas which serve mainly stationary users (those who have boats permanently moored), seasonal users (whose boats are moored only in some periods of the year) and in-transit users that use infrastructure and services occasionally. Boats are small; users are usually dynamic and independent. For both cases, demand is not stable and consistent enough to justify neither regular nor on-call public transport service.

A proper bike share system could be a good solution to deal with this kind of mobility need. While services might appear appealing on a first sight, a careful design is expected for the service to be successful and effective. Limiting factors for cruisers in using bike sharing are most of all the lack of infrastructures and factors related to their knowledge gap, which include both capability items (autonomy, easiness of utilization, clarity and availability of information, safety and equipment) and items related to users' confidence (i.e. the need to subscribe to a program, privacy issues, disclose credit card data).

As we will see in this paragraph, financial autonomy is a crucial aspect, as the need to run a service which is healthy from the economic point of view has to be balanced by the necessity to tailor the fares in such a way that users are attracted. First of all, tariffs shall be low and transparent for users (i.e. fixed price/time threshold, safety equipment charged as extra service or not…). On the other hand, service shall cover the high costs connected to vehicles' and stations' maintenance, operating costs, bikes' redistribution, personnel. In this context, also advertising and other funding sources (i.e. crowdfunding or EU funds) are helpful in scoring the aim of financial sustainability.

As mentioned before, bike-sharing is established worldwide for citizenships and less for tourists. Starting from the end of the 1990s, cycle tourism has begun flourishing in particular in those countries with established bike culture; this form of tourism is usually combined with longer trip segment carried out by private car or rail. For those not travelling with their own bike, bike sharing opportunities to visit urban context in a sustainable way are welcome as they are enjoyable, relatively cheap and door-to-door. A good level of infrastructure (segregated bike paths and routes) is desirable and attractive (Kaplan et al., 2015; Bakogiannis et al., 2018) if accompanied by tailored and fair tariff scheme (long term program for residents and frequent users, short term programs without constraints related to usage time or distance covered for tourists) included in the urban integrated transport plan of the city (Cavallaro et al., 2017) and clear-cut communication and instruction in many languages. SUMPs in Europe shall be developed and encouraged accordingly.

3.1 The Croatian experience

Only in the last few years some bike sharing programs have reached Croatia and are managed by the private company Nextbike in some of the biggest cities of the country

(Zagreb, Zadar, etc.). In Pula a European program (MOVESMART) was launched in 2013 to promote the use of sustainable mobility among citizenship by means of a fleet of 18 e-bikes that could be picked up and dropped off from 3 stations without any time limitation and at a very low cost in order to encourage the use of this solution.

3.2 The Spanish experience

Valencia is the third biggest Spanish city and one of the biggest industrial and commercial harbors in the Mediterranean area. Favored by the touristic vocation of the center and the good level of maritime infrastructures, the cruise sector attracted around 400,000 passengers in 2018 and is still growing. The Port Authority and the local Touristic bureau - concerned about making the city more attractive without harming sustainability – launched a six-month pilot project where tourists could rent as much as 10 e-bike to reach the city center (6.5 km away) from an automated depot located at the pier. The service was target on younger people (25-45 years) and dynamic adults; it foresaw no human assistance for reservation, pick-up and drop-off, a smart locker with GPS integrated for e-bikes and solar panels to run the depot and supply the battery charge device (around 4 hours). The service was funded by the European Community through the INTERREG projects SUMPORT (75%) and by the Valencia Port Foundation (25%). The initial budget was 8,000 € as the bikes were issued for free by the provider which was a partner of the project. Tariffs scheme encouraged one day rental (24 €) while, later on, short hire was allowed at a reduced price (9 € / 1 hour, 18 € / 2 hours). Despite ad & media campaigns and assistance at the tourist bureau and at the depot, the project was closed at the end of the pilot. Cruise companies were not interested in the service as passengers' transfer (even by bike) is usually included in the holiday package.

3.3 The US experience

"Quikbyke" is to authors' knowledge the only successful application of mobile depot equipped for bike sharing or rental. Effective features of the service are: (i) the possibility to move the depot between location to satisfy the seasonal profile of flows, (ii) a strong economic structure - the project is a spin-off of an established e-vehicle manufacturer and has been funded by private money, a grant of 27,000$ from the Nebraska Department of Economic Development and online crowdfunding, and (iii) it is tailored for touristic locations. The first prototype was launched in 2016 in Omaha (Nebraska) during summertime and then moved to the warmer Florida in winter to serve the cruisers. The shop is a re-engineered side-entry 20-foot shipping container equipped with a rooftop solar array feeding power supply and the bank for six lithium-ion batteries. The shop can be displaced easily by ship or truck. E-vehicles have a range of 40-50 km, depending on rider input and local terrain. The tariffs scheme is simple (5$ / 60 minutes in the Omaha pilot, which is still higher than the average) and allows financial equilibrium so that the project is being expanded in new locations (the Caribbean area), where both demand and environmental awareness are present (small towns, high tourist flows, peculiar culture …). The "shop-in-a-box" system was conceived for up to 10 e-bikes and to be manned by one or two attendants during business hours to serve the clients, maintain the bikes, lead tours, and sell merchandising. They add human touch to the experience – in particular by advising guided tours and must-see places - but also add to the operating costs.

3.4 The Italian way

In addition to the ones cited above, many others exist on varying the focus of the program. The main differences are related to the users (commuters, tourists etc..), the business models (public, private), the vehicle type (traditional bikes or electric ones) and the project's size (municipal programs, private pilots etc.). Station-based bike sharing system is the most popular solution for public projects but need high investment in infrastructure and large fleet to serve the demand. Free Floating bike sharing systems allow to collect/drop off and pay for the bike by means of remote devices and without fixed stations. In both cases, vehicles' rebalancing within the area is a significant cost source. Bike rental are leisure-oriented services with only one base station; tariffs are quite high and flexibility during off-season periods is scarce.

The mobile bike depot is a mixed solution which collects all the strongest aspects of solution above to serve seasonal and discontinued demand profiles which are typical of touristic locations.

Rather than case studies, literature is mostly concentrated on behavioral and policy aspects, in particular related to the un-even introduction and regulation of e-vehicles worldwide.

4 The MOSES project framework

4.1 The geographic context: Ravenna

Ravenna is the only port of Emilia-Romagna Region and an important sea gateway to Central Italy, Emilia-Romagna Region, Republic of San Marino. Besides, the city of Ravenna has easy and quick access to Venice by regional trains and is linked to high speed train lines via Bologna, from where cities such as Florence, Milan, Rome can be reached in less than 3 hours. Several sea routes connect Ravenna to Slovenia, Croatia, Montenegro, Albania, Greece and other ports in Italy. For all these reasons, the Ravenna port has a big potential in terms of touristic attraction. Despite that, the passenger flows in Ravenna Cruise Terminal are not so high. Based on the Ravenna Port Authority data, the Ravenna cruise terminal has an average of **45,000 passengers per years**, despite the touristic potential of the Ravenna port is about **80.000 passengers per year**.

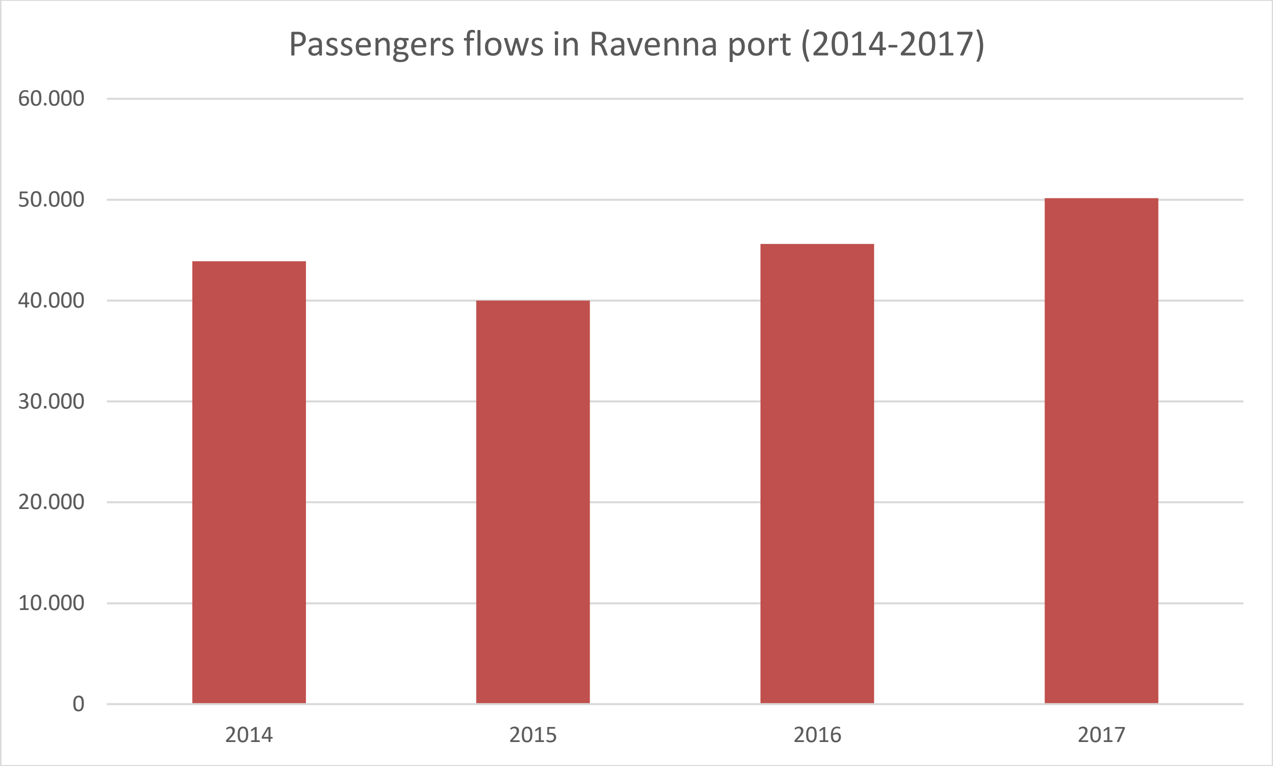

Figure 1. Passengers flows in Ravenna port (2014-2017). Data source: Ravenna Port Authority (2019)

The Ravenna cruise terminal is located **20 minutes' drive** from the Ravenna historical city center. The Ravenna Cruise Terminal is located in the Porto Corsini waterfront, about **12 km** from the city center. The Terminal is able to accommodate ships up to 280 meters in lenght.

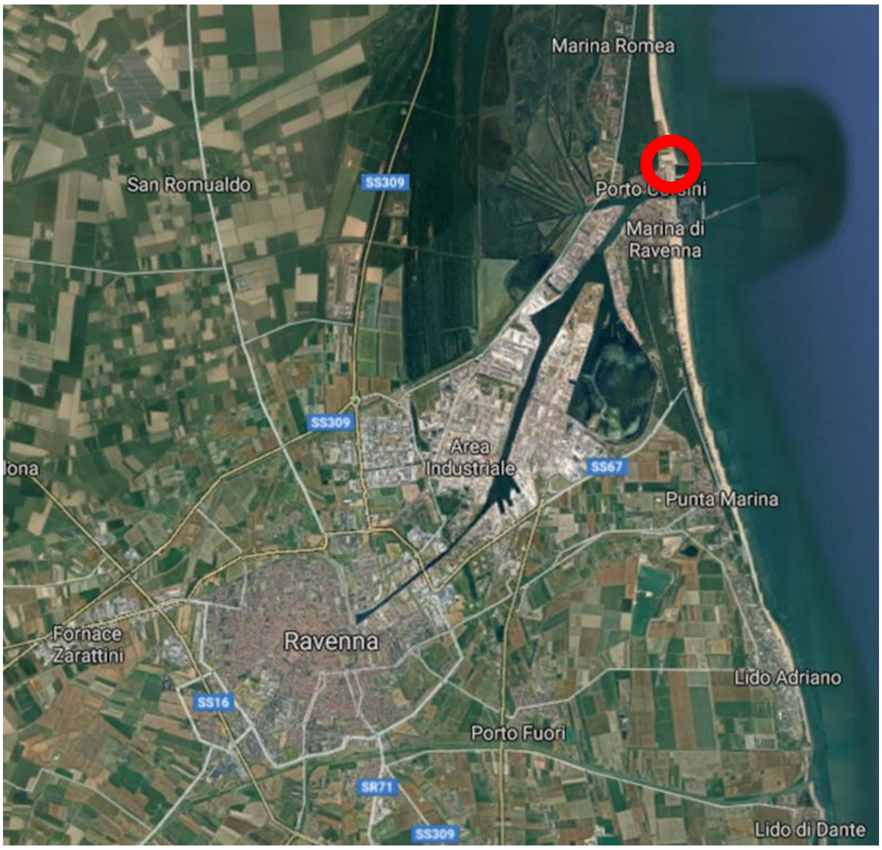

Figure 2. The Ravenna Cruise Terminal location in Porto Corsini, Ravenna

The public transport connections between the port and the inland city center are not adequately developed, with only one public transport bus line (line 90) connecting the cruise terminal to the city center. Moreover, the bus stop is quite detached from the Ravenna cruise terminal, thus reducing further the number of potential public transport users.

4.2 The Ravenna pilot description

The Ravenna pilot was developed and financed in the framework of the Moses (Maritime and multimOdal transport Services based on Ea Sea-Way project) Standard-plus project financed by Italy-Croatia CBC Programme 2014-2020 based on the main results of the IPA Adriatic project EA SEA-WAY. Project partners are Autonomous Region of Friuli Venezia-Giulia (lead partner), Institute for Transport and Logistics (ITL Foundation), Primorje-Gorski Kotar County, Molise Region and Region of Istria. The Moses project objective is to improve the accessibility and the 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 scope of the Moses pilot in Ravenna was to design, implement and test an innovative service of electric bikes sharing aimed to promote sustainable intermodal solutions between the Ravenna port area and the Ravenna city center.

There were different reasons for choosing an electric bike to provide a sharing service in areas with high variable touristic demand:

- Batteries allowing more than 40/50 km of autonomy;
- Easiness to charge batteries;
- Easiness to use;
- No license needed in the Italian context;
- Lower costs compared to others sustainable transport solutions.

In brief, these were the main numbers related to the Moses Ravenna pilot:

- **18 electric bikes** (different models for woman and man);
- **1 electric tricycle** for disabled people;
- **19 GPS system** managed by an online platform;
- **1 container 40’’** transformed into a prototype “**Mobile Hub**”.

The Mobile Hub has been conceived as a flexible and low-cost hub for the storage and maintenance of the electric bikes. There are different reasons supporting the development of this kind of solution:

- “Mobile” to meet seasonal characteristics of the cruise services;
- “Mobile” to provide services in different points;
- “Mobile” to allow the transferability to others Adriatic ports.

Figure 3. The Moses Mobile Hub and the electric bikes used for the pilot activities in Ravenna

In relation to the Moses pilot in Ravenna, different kinds of e-bikes were used in order to provide a service suitable both for man and women and considering the high average age of cruise passengers in the Ravenna port area, both for old and younger people.

Table 1. Technical information on the 3 different e-bike models used during the pilot test in Ravenna.

	FIVE Wayel Suv	FIVE Wayel Futura	FIVE Tricycle
Engine Power	250 W (19 nm of torque)	250 W (32 nm of torque)	250 W (30 nm of torque)
Battery	Lithium ion cells Samsung 24v 8.8 ah (8.8 ah nominal capacity)	Lithium ion cells 36v 10 ah (10 ah nominal capacity)	Lithium ion cells 36v 8.8 ah
Autonomy	30 – 45 km	50 km	50 km
Weight (kg)	23.3 kg	23.3 kg	33.3 kg
Wheels	Rear 26'' – 1.75'' – Anterior 24" – 1.75"	Rear – Anterior 28" – 1.75"	Rear – Anterior 26" – 1.75"
Market price (2018)	1.200 €	1.300 €	1.800 €
Number of bikes in the Moses Pilot	8 (Unisex)	5 (man model) + 5 (female model)	1

There is a wide literature showing the importance of high-quality bikes in order to guarantee high success rate of the bike sharing renting systems. In fact, bikes perceived as not reliable in providing the required service reduce the appeal of these sharing services. This is more important for an electric bike sharing services, where users decided whether to use or not the service also depending on the reliability of the electric bikes in covering long distances as the one considered in the Ravenna Moses pilot (more than 35 km per a return trip from the Ravenna Cruise Terminal to the historical city center).

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4.3 The electric sharing service testing period in Ravenna

The pilot was conducted during the **Summer 2018** from July to October. Due to technical and administrative problems, it was possible to provide the full electric bikes renting services during **6** berthing days in the Ravenna port. These cruise ships for which the sharing service was activated were:

- Amara Quest on 30/09/2018. Ship capacity: 680 passengers;
- Monet, Elegant Cruises on 19/10/2018. Ship capacity: 90 passengers;
- Monet, Elegant Cruises on 26/10/2018. Ship capacity: 90 passengers;
- Marina, Oceania on 27/10/2018. Ship capacity: 1.250 passengers;
- Pacific Princess on 28/10/2018. Ship capacity: 640 passengers;
- Pacific Princess on 21/11/2018. Ship capacity: 640 passengers.

In total **3.390 cruise passengers** were the potential users of the sharing service. Despite this potential, only 28 rentals were provided during the testing period and in particular:

- **26 users on 30/09/2018**, ship Azmara Quest, stop duration in Ravenna port: 8:00-16:00;
- **2 users on 27/10/2018**, ship Marina Oceania, stop duration in Ravenna port: 8:00-18:00.

Figure 4. Photo from one renting day in Ravenna Cruise Terminal.

The low numbers of rentals were mainly due to two main causes: bad weather conditions during some rental days and touristic trips sold on-board or included in the holiday package organized by the cruise company and based on reserved bus services.

In relation to the bad weather conditions, strong wind forbade the ships from docking or rain discouraged potential users from using the bike.
In relation to organized tours, the largest part of the cruise tourists arriving in Ravenna used preserved touristic buses to reach the Ravenna city center. These tours were organized and sold directly by the cruise companies. The same problems were traceable also in the similar pilot developed in Valencia port described above. For all these reasons, it is possible to infer that **independent travelers** and the **cruise crew** are more likely potential users of this Moses electric bike sharing service.

Bad weather conditions and organized bus tours reduce the number of electric vehicles sharing services' potential users.

4.4 Service users' survey

During the Moses pilot activities, 28 e-bike rides were registered and monitored thanks to a dedicated survey. Of those, **5** users were crew members, the others independent passengers.

Table 2. Surveys collected per Country

Country	N°
Canada	15
USA	4
Australia	2
Italy	2
Philippines	2
Scotland	1
Unknown	2
Total	28

As evidenced in the table above, most of the Moses electric bikes sharing service' users were foreigners, mainly coming from the US and Canada.
In relation to the users' age, it is possible to see as the average age was quite high. This was an expected result, as others survey campaigns conducted in the past showed similar results.

Table 3. Data on Moses electric bikes users' age

	Age
Average users' age	**48**
Maximum users' age	**78**
Minimum users' age	**25**

This data confirmed one the Moses pilot objective, namely the use of the electric bike as an attractive, reliable and sustainable solution for aged tourists arriving in port areas. As demonstrated by these data, electric bikes could be a valuable solution for aged people with reduced mobility or not able to use traditional bikes, even in covering long distances.
Many of the Moses sharing service users were "first-timers"; this is a very interesting data as it confirms that sharing services are able to promote electric mobility among people. On the other hand, as evidenced in the scientific literature on these topics, the higher than

average price of electric vehicles (cars and bikes) is one of the biggest barrier to penetration in the market.

Table 4. Data on electric bikes previous experiences.

First time using an electric bike	
Yes	20
No	8

This data, although not representative from a statistic point of view, confirmed the importance of sharing services in disseminating an increased awareness and culture on electric mobility.

The sharing services provided with electric vehicles has a great importance in disseminating electric mobility awareness and culture among general users.

During the Moses pilot activities in Ravenna, all the electric bikes were provided for free. Starting from the limited number of replies collected, it is possible to notice that on average people were available to pay as much as **15€ - 20€** for a daily rent of an electric bike.
In relation to the service satisfaction level, the **100%** of the Moses sharing service users declared to be very satisfied on the service. The same result was scored as far as the perceived quality of the electric bikes was concerned.
During the conduction of the testing activities, no problems occurred in using electric bikes apart from 2 tires deflated
In relation to the cycling infrastructures quality in the study area, all the users ranked 10 on 10 the quality of the cycle infrastructures outside the Ravenna Cruise Terminal (cycle paths, cycle crossing, road signage, etc.). All the users declared to had found in the Ravenna Cruise Terminal all the needed information to organize the electric bikes trips. In relation to this topic it is important to underline as during the whole Moses pilot activities a dedicated person in charge of providing all the required touristic information to the cruisers was available within the cruise terminal. Finally, the large part of the respondents declared that the Ravenna Cruise Terminal's sustainable transport offer was better compared to the other ports visited during the cruise.

5 GPS quantitative data. The monitored Moses users' cycle itineraries

In the framework of the Moses project, each rented electric bike was monitored using a GPS device. Despite some technical problems, it was possible to collect high quality and representative data. The main technical problems faced in managing these GPS systems were mainly related to:

- GPS detection errors due to external factors, as the number of visible satellites and the precision of the monitored points (See Annex 2);
- Unpredictable interruptions in the journeys' monitoring due to exhausted batteries and loss of GPS signals, etc.

For all these reasons, a **geometric simplification of the monitored cycle itineraries** was conducted in the post-processing phase in order to have relevant and smooth data. Where the GPS data were missing, the information needed were inferred from the surveys.
Considering all these ex-post geometric simplifications, 5 different cycle itineraries typologies were identified as summarized in the table below.

Table 5. Synthesis of monitored cycle paths

	Cycle itinerary typology	Length (km)	Intermodality	N° users	Points of interest
1	*Double Pier path in Porto Corsini and Marina Ravenna*	7.1	Ferry	2	Pine forests Marina di Ravenna Beaches
2	*Single Pier path in Porto Corsini*	3.4	No intermodality	5	Pine forests
3	*Marina di Ravenna path*	4.8	Ferry	13	Marina di Ravenna Beaches
4	*Ravenna city center path (one way, return by bus)*	15.1	Ferry Bus	2	Ravenna city center Pine forests Marina di Ravenna
5	*Ravenna city center path (return trip)*	31.8	Ferry	6	Ravenna city center Pine forests Marina di Ravenna

The 5 different cycle itineraries differ on the basis of their lengths and intermodal degree. In relation to the travel intermodality, it is interesting to note that almost all the electric bikes users made use of the public ferry transport service connecting Porto Corsini to Marina di Ravenna.

The use of light electric vehicles in sharing mobility services allow to cover in a reliable, efficient and attractive way long trip distances (more than 30 km).

As highlighted in the Table 6 below, during the Moses pilot test activities in Ravenna, the total distance travelled surveyed was **314,6 km**, allowing to obtain relevant data from a statistic point of view.

Table 6. Total km travelled by Moses electric bikes during the Moses pilot in Ravenna (Summer 2018).

	Cycle itinerary typology	Length (km)	N° users	Total km travelled
1	Double pier in Porto Corsini and Marina Ravenna	7.1	2	14.2
2	Single pier in Porto Corsini	3.4	5	17
3	Marina di Ravenna	4.8	13	62.4
4	Ravenna city centre (one way)	15.1	2	30.2
5	Ravenna city centre (return trip)	31.8	6	190.8
	Total	62.2	28	**314.6**

Thanks to the GPS tracking technology, it was possible to map in detail the bicycle itineraries generated by each user.

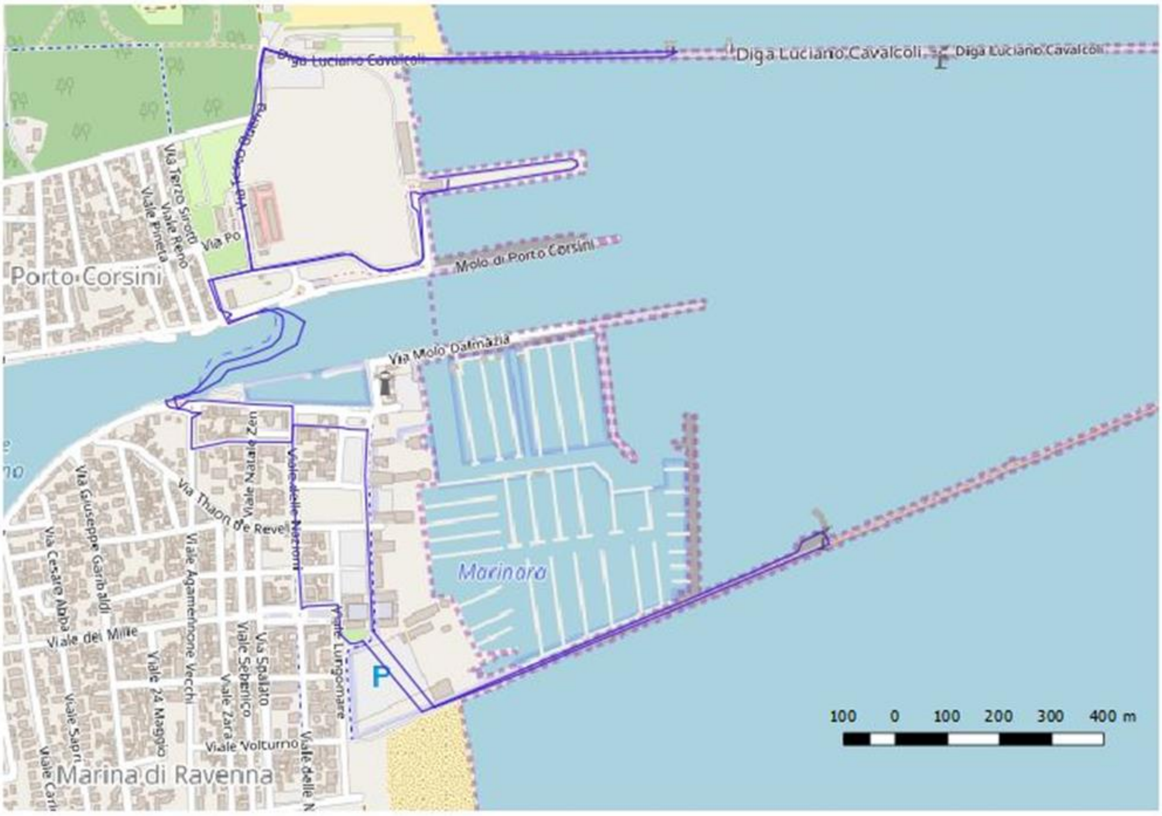

Figure 5. Path 1. Double pier path in Porto Corsini and Marina Ravenna (Source: ITL Foundation elaboration)

The Path 1 “Double pier in Porto Corsini and Marina Ravenna” main aim was to reach the touristic beaches and the restaurants located in Marina di Ravenna, one of the most important and attractive touristic areas in the Ravenna municipality. The electric bikes were also used to reach the two piers, both attractive from a landscape point of view. Path 1 total length amount is 7.1 km.

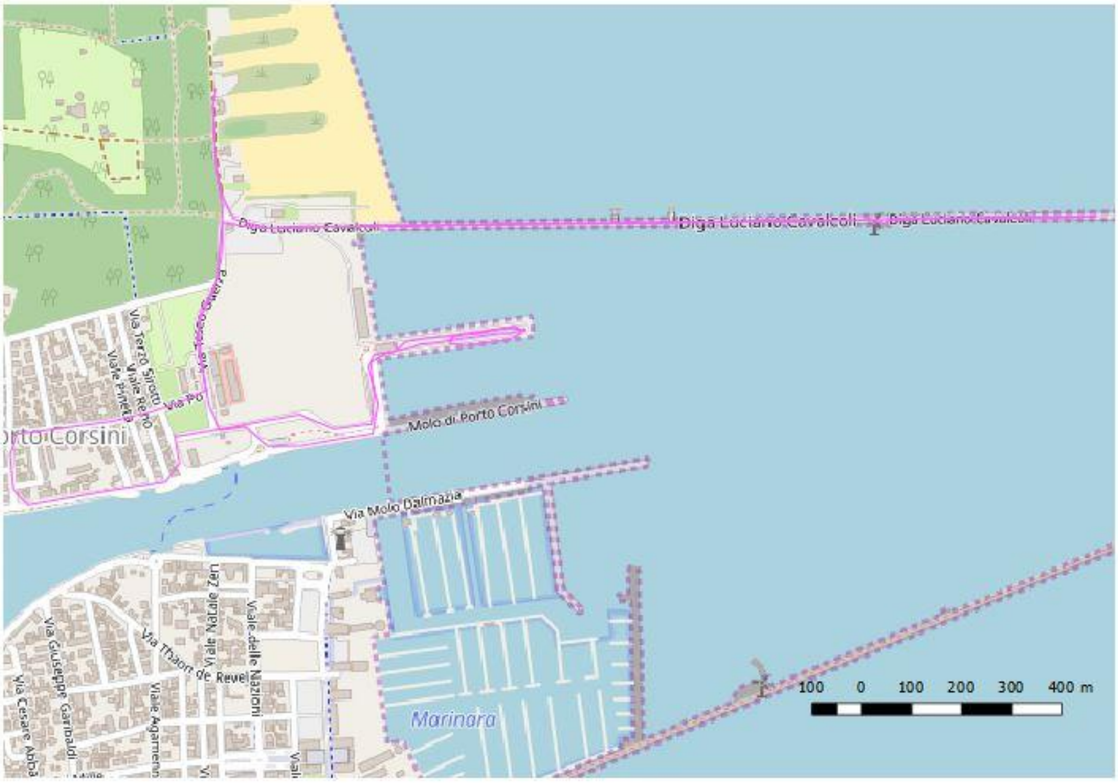

Figure 6. Path2. Single pier path in Porto Corsini (Source: ITL Foundation elaboration).

The Path 2 “Single pier in Porto Corsini” was the only collected path were the ferry service was not used. In this case the electric bikes were used for very short distances in order to reach the pine forest in northern part of Porto Corsini municipality and to reach the northern pier, an attraction mainly for local people. Path 2 total length amount is 3.4 km.

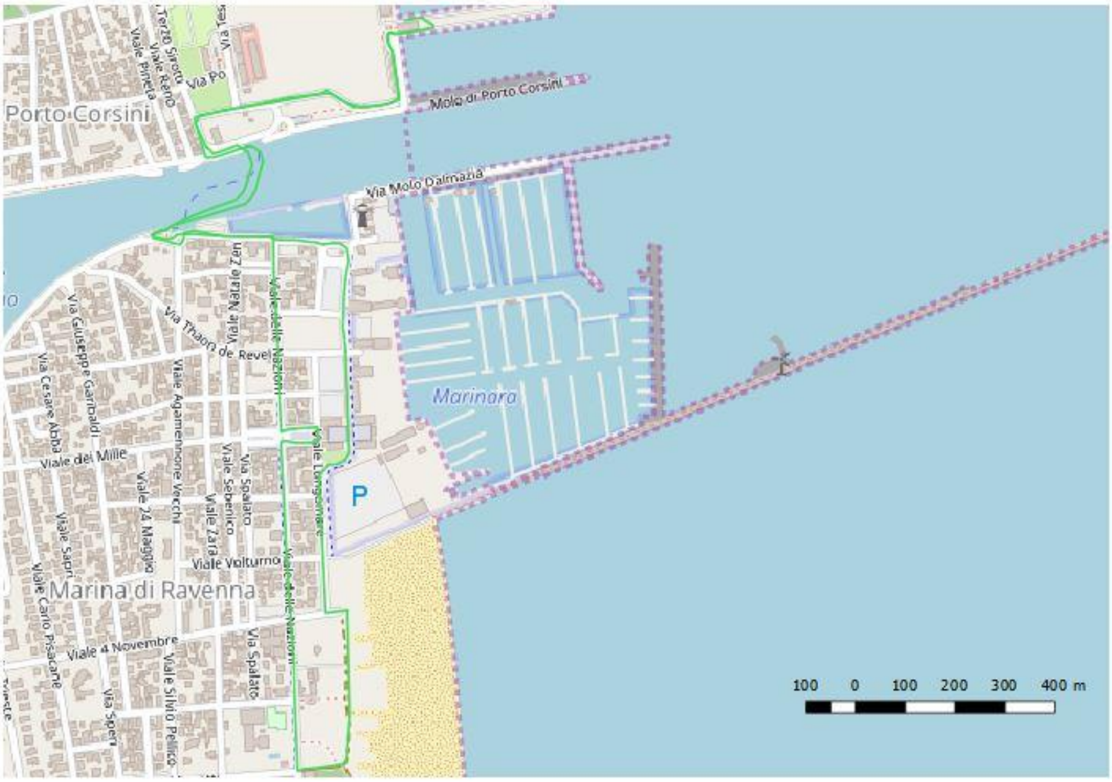

Figure 7. Path 3. Marina di Ravenna path (Source: ITL Foundation elaboration).

The Path 3 “Marina di Ravenna” main aim, as for Path 1, was to reach the touristic beaches and restaurants located in Marina di Ravenna, one of the most important and attractive touristic areas in the Ravenna municipality. Path 3 total length amount is 4.8 km.

Figure 8. Path 4. Ravenna city centre path (one way) (Source: ITL Foundation elaboration).

The Path 4 “Ravenna city center one way” is the most interesting one for the purpose of the Moses project. One of the most important objectives of the Moses pilot in Ravenna was, indeed, to demonstrate that the electric bikes could be a reliable and efficient transport solution between the cruise terminal and the Ravenna historical city center. In this case, users reached the city center by a combination of the public transport ferry service to cross the “Candiano Channel” and e-bike. Once in the city center, one of the user experimented a minor technical problem (tire deflated) so they decided to return to the Cruise Terminal by using the public transport. Based on their qualitative notes collected during the survey, they appreciated the different transport services used and they reported a perfect degree of integration between the two transport solutions.
Another very interesting aspect showed by this test case is related to the use of the existing cycle paths connecting the Ravenna cruise terminal to the historical city center. The users, following the indications provided by the personnel at the port, followed existing cycle paths to reach the city center. Based on the qualitative data collected from the survey, they declared they would have never been able to reach the city center were these infrastructures not present. Path 4 total length was 15.1 km.

Cycle paths are fundamental in order to promote more sustainable transport solutions.

Figure 9. Path 5. Ravenna city centre path (return trip) (Source: ITL Foundation elaboration).

The Path 5 "Ravenna city center and return trip" is similar to Path 4, but in this case the users were able to get back to the cruise terminal without using public transport service. For both trips, the users followed the existing cycle path network. Path 5 total length was 31.8 km.

6 Scope for replicability of the MOSES pilot case

As it has been mentioned in the sections above, the financial aspects connected with services of this kind are of paramount importance (van Waes et al., 2018). The pilot cases examined have been funded and started under the terms of public grants, EU research projects and crowdfunding which have no doubt been helpful in ensuring at least the partial coverage of infrastructure and fleet costs. Therefore, it has to be kept in mind that replicability is possible only under determinate conditions on varying the context, the scope and the size. In the table below a summary of the principal cost and profit items is presented. A particular focus is worth on the topic of how to dispatch the mobile depot, since it is the main source of novelty with respect to traditional bike sharing solutions.

Table 7. Principal cost and profit items connected with the replicability of mobile depot pilot.

	Cost items	**Profit items**
1	Fleet (1,500 €/bike)	Rental activities – dependent on the tariff scheme
2	Spare parts and safety equipment (ie. helmets, lights, bells, GPS, lockers, batteries …)	Bike tour
3	Periodic maintenance (a contract with the bike vendor is advisable)	Merchandising

4	Personnel	Crowdfunding and grants
5	Permit for occupation of public land, expenses for energy (if not energetically self-sufficient)	Online purchase made by users and profits related to advertising
6	Re-engineering of the container (side or front opening, layout, desk, bike storage device, power bank for batteries)	/
7	Full solar panel supply	/
8	Advertising, media campaign, brochure, leaflets both on-site and on-vehicles (branding) Website, app, map tools	/
9	Insurance scheme for personnel and users	/
10	Displacement	/
11	Optional wifi recharge technology	/

Large commissioning of vehicles and spare parts as well as long-term agreements for periodic maintenance allow to bargain for lower prices. It is advisable, on the other hand, to scale such investment with reference to the expected utilization. All the cost items can be expressed as a share of cost item n°1. For example, spare and extra equipment can account for as much as 10-15% of the cost of the vehicle and the periodic maintenance program for another 10%. The average life of each vehicle is assumed equal to 2 years; as far as batteries are concerned, the duration is expressed in number of charge cycles and we assume 200 cycles/year and to replace exhausted batteries every 2 years. Depending on the quality, e-bike average cost range is between 1,400€ and more than 8,500€ for high-end and mountain bike models. Battery – and henceforth range – is of crucial importance and it is one of the items on which money is not worth to be spared: on varying quality and brand of the battery, range can vary between 25 and 100 km depending on the user's weight, the cruise speed, the battery age and the morphology of terrain. Ordinary batteries would cost 150€ - 300€, while a premium lithium-ion battery for e-bikes costs from 400€ to 800€. Lifespan, accordingly, spans between 3 and 10 years of declared efficiency. It is advisable that the number of batteries would be bigger than the number of e-bikes so that to provide the users with an additional – full charged – battery in case of longer rent. Most components (tires, brakes, chain) are generic between e-Bikes and normal bikes but wear out quicker due to the higher speed allowed by the motor. The annual cost of basic maintenance and spare parts ranges between 100€ – 200€. The electrical part generally will require little maintenance (in case of issues, most probably they need replacing rather than maintenance). The charging costs from the network are negligible: a 400Wh battery multiplied by the average price of energy (0,06€/kWh in Italy), by the average time required to reach a complete charge and by 365 returns an annual cost of less than 30€/year/battery. Safety and security items must be of very high quality: lights and bell are worth additional 50€; besides U-lock, also smart locks which combine security and performance tracker functions are available on the market at a slightly higher cost (120 € VAT excluded). As a consequence, an average yearly cost of as much as 33,000 €/year is assumed.

MOSES as well as some pilot projects evaluated in the state-of-the-art review phase have been designed to be self-sufficient with a few personnel units available on the spot for basic instruction to users. Quickbyke instead foresees personnel to add human touch as a determinant of success. Under these premises with 3 personnel units to cover weekly workshift a gross wage of 6,000 €/month is assumed. Public land use permission depends on the location chosen and on negotiations between service provider, local authorities and stakeholders. An additional 1,000 €/year are assumed as a consequence.

The cost concerning the re-engineering of the 40ft container unit have been assumed equal to as much as 15,000€, here included a two-tier rack to store bicycles and the furniture, based on some costs and items found on the internet.

The cost of solar plant is a variable: project solutions differ between fixed plant - which can be arranged on the rooftop of the depot - and mobile/portable solutions, which are or reduced dimensions, less heavy and even disposed on tissue so that they can be easily folded so that to reduce the bulkiness when not used. On varying the size and the requirement (i.e. light and lamp typology, number of batteries to be charged simultaneously…), dimension and price are expected to increase. To reduce the dependency on weather condition, panels shall be equipped with devices to stockpile the energy in order to ensure energy also in cloudy and shadowed contexts. E-bike batteries can be technically charged with solar panels, but different voltage complicates things. In addition, energy needs to be stored to charge the batteries overnight. Theoretically, a good quality 12 V, 20 W, mono-crystalline solar panel will produce approximately 14 V at 1.3 Ah (under load); 4 x 20 W panels would approximately return the same performance of a standard 48 V e-bike charger, but they would need almost 2 days of bright sun exposure. Home solar plants are mounted over rooftops and harvest energy all day, as long as the roof isn't shaded. Foldable solar panel chargers are useful for people going on camping to supply power to PC, phone, power stations, they are worth in between 20 - 100W and they cost 100 – 200 € each! E-bikes have a powerful motor and therefore a powerful battery to carry on people worth 80kg for 50km range on average! Therefore, if we assume to run the mobile depot by relying only on solar energy, we need to design the storage system and the number of solar panels needed based on the output energy required to charge the batteries during the evening and night hours. E-bikes adopted in MOSES have batteries 36V 10Ah = 360 W = 0,36 kW. By assuming that we have the whole lot of 30 batteries out of charge at the end of the day, a total supply of 0,36 x 30 = 10,8 kW is necessary for 5 hours. In Italy, a typical 3 kW solar plant to run a domestic plant will cost as much as 5,000€ with solar tax credit 50%, which makes up 0,85€/W. A feasible solar generator supplier system capable of supplying the power needed would cost around 16,0000 €. Both re-engineering cost of the container and the solar supplier system are single-event costs; by assuming a 10 years life-time, they return a combined 3,100.00 €/year cost.

Containers are traditionally handled in logistic platforms by means of cranes, reach stackers and side loader. The cost of such vehicles is extremely high and has to be justified by the number of operations per time unit. As far as mobile depot is concerned, such vehicles can also be rented and made available on call, but also the single operation is not negligible from the monetary point of view. In Italy there is only one operator that offer the combined service of lift and transport of containers by road. The cost of each single lift operation would cost 70 €, and the cost/km for displacement is 1,45 €/km which can be reduced when the distance travelled increases. Displacement costs are divided into two items: handling at nodes A & B (origin and destination of the journey) and transport costs between A & B. We assume to use a third part on call transport provider whose truck is equipped with a sideloader. The total cost per year can be adjusted in case a plafond of trips is foreseen in advance. The transport cost item is referred to distances ranging between 50 and 600 km (one way distance) to account for the displacement of the mobile depot between Ravenna port and other principal port infrastructures in Italy, located both in the north and south or on eastern and western coast of the country. By assuming that the mobile hub is disposed between 4 locations each year (whose road distance from Ravenna port spans between 180 and 500 km by road) and taken into consideration handling cost and dead cost for displacement of the sideloader from its base station, we obtain an average cost of 5,600.00€/year.

For advertising 3,000€/year are assumed, based on ad campaign at the local level, brand registering, web domain, buyout and creation of brand merchandising. To conclude, a prototype modified kickstand to allow wireless recharge by means of the magnetic field generated by the tile has been found on the web, which is looking for implementation tests on a market setting.

By summing up the cost items listed above, a total round off cost per year of 120,000.00 € is obtained. Under those hypotheses, it is adamant that the profit items (Rental activities, tariff scheme, Bike tour, Merchandising, Crowdfunding and grants, Online purchase, and profits related to advertising) have to be carefully assessed in order to reach financial sustainability. As a preliminary assumption 12 hour service (8.00 am – 8.00 pm), a tariff of 3 €/hour (bike + rental of safety equipment) – 5€/2 hour – 10€/4 hour - 15€/6 hour – 25€/day, a tariff of 7€/person for guided tours, a price of 10€ for T-shirt and 3-5€/item can be proposed. By assuming that 20 bikes out of 30 are actually used for 300 out of 365 days/year, for 7 out of 10 hours/day at 3€/hour, a return of 126,000.00 € is obtained, meaning that the project can be viable. Further profits can be raised by means of merchandising and guided tours.

The most relevant cost and profit items have been listed and evaluated under standard business hypothesis to assess the financial sustainability of the project.

To score the goal of financial sustainability, strategies have to be designed to (i) actively seek the support and feedback from local communities (i.e. subsidies and supporting infrastructure), public-private partnerships with stakeholders as well as with the vehicle's manufacturer; (ii) mirror travel demand and users' needs as far as infrastructure and user-friendly interfaces are concerned; (iii) drive a cultural and behavioural change by means of a step-by-step assessment and revision of the project to encourage the users' involvement.

7 Conclusions

The Ravenna case study developed and assessed during the Moses EU project demonstrated qualitatively and quantitatively that a flexible and low-cost electric bike sharing service developed in a small/medium port area could:

(i) balance the strength points of established cycle-based public transport systems;
(ii) address the seasonality issue connected to touristic flows and sustainable transport solutions;
(iii) fill the gap in the scientific literature on the niche topic of sustainable and affordable mobility solutions for touristic ports and marinas.

In particular, the quantitative data collected in the paper demonstrates that the use of light electric vehicles in a sharing mobility service allows to cover in a reliable, efficient and attractive way long trip distances (more than 30 km). Moreover, the use of electric vehicles in this kind of sharing mobility services is an attractive, reliable and sustainable solution for aged tourists arriving in port areas also to cover long distances.

Light electric vehicles, as demonstrated by the data collected during the pilot project in Ravenna, are also a suitable and reliable way to provide and promote intermodal and sustainable transport solutions in urban and low density/peripheral urban areas. In fact, light electric vehicles allow an easy integration with existing public transport offer (both buses and urban ferries) and potentially also with trains for longer distances.

Moreover, the qualitative data collected with dedicated surveys administered to users showed the importance of supporting all these electric mobility initiatives with high quality infrastructures, in particular safe and well-designed cycle paths. In the Ravenna case study, the existence of a cycle path connecting the port area to the historical city center had a

fundamental role. In fact, as evidenced by the qualitative data collected from the survey, the users declared they would have never been able to reach the city center weren't the cycle paths available.
In relation to the business models and replicability of electric vehicle sharing services of this kind, the collected data and the literature evidences show that the costs are often too high for a wide dissemination of these services in areas with high variable demand and/or peripheral areas. Moreover, the "Mobile Depot" solution tested in Ravenna during the Moses project demonstrated as alternative and more cost-efficient solutions to provide electric sharing mobility services in small/medium port areas are present. Based on a preliminary economic assessment conducted in the framework of the Moses project, it is possible to quantify that Mobile Hub allows to reduce by 15-20**%** the costs of providing an electric bike sharing service. In addition, a preliminary balance sheet has been outlined, showing that under a careful assessment of costs and profits (obtained by rental activity, side activities such as guided tour, merchandising, online booking, advertisement, crowdfunding and discounts/grants/subsidies obtained by project partners, municipalities and stakeholders) the activity can be economically sustainable.

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