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Additional Report on the technical and economic sustainability of the Moses "Mobile Depot" tested in Ravenna Port

Business model for the replicability of the Moses Ravenna pilot

Index

PART 1. LITERATURE REVIEW ON BIKE SHARING AND ON ELECTRIC BIKE SHARING SYSTEMS

In accordance to Interreg Italy-Croatia JS and LP, ITL had activated an additional technical and economic study aimed to analyse more in deep (both from an economic and technical point of view) the replicability of the Moses Ravenna pilot in others contexts. The main technical analysis and conclusions are reported in this additional report. The first part is dedicated to an analysis of the main literature and practices related to the use of bike sharing and electric bike sharing systems as an effective last mile sustainable transport solution. In the second part, a technical analysis is conducted in order to analyse in deep the replicability framework of the last mile solution tested in Ravenna in the framework of the Moses project.

1. BIKE SHARING DEFINITION AND FEATURES

In the last few years bike sharing has become one of the most interesting urban mobility options and has gained popularity all around the world (Kou & Cai, 2019). According to some authors (Midgley, 2009) (Bakogiannis, et al., 2016), we could say that bike sharing has experienced the fastest growth in the history of the planet among the existing means of transportation. We could simply define it as a shared use of a bicycle fleet (Shaneen, et al., 2010). In more specific terms, bike sharing “system” or “scheme” is based on some principles, namely the self-service, short-term and one-way-capable bike rental. The service is offered in public spaces for several target groups, with network characteristics (Bakogiannis, et al., 2016). Individuals can use bicycles on an as-needed basis without the costs and responsibilities of bike ownership (Shaneen, et al., 2010). Users can access public bicycles at unattended bike stations and manage all the different phases of the process (reservation, pick-up, drop-off) on their own. The stations network allows users to make point-to-point trips (Zhu, 2018) and eventually return the vehicles to a different station. In addition to this, every bike sharing program normally covers bicycle purchase and maintenance costs, as well as storage and parking responsibilities (similar to car sharing or short-term auto use) (Bakogiannis, et al., 2016). The vehicles’ short-term rental is encouraged by tailored fees that combine a certain amount of time (up to 30 minutes) granted for free and then a fixed tariff for time unit (Zhu, 2018). Even if bike sharing and bike rental have some common features, we can assert that the latter is more oriented to leisure mobility and for every trip the end stations usually coincide. This is why the service is focused on private use, with an hourly pricing basis. Bike sharing systems share some of these aspects but have some additional characteristics (Midgley, 2009):

- the possibility to rent a bicycle at one location and either return it to the original station or to another designated location;
- fast and easy access;

- diverse business models;
- use of integrated technology (smart cards or mobile phones), which often makes this solution part of a public integrated transportation system.

An important element that underlines the difference between bike sharing and bike rental is indeed the business model. In fact it's possible to classify bike sharing systems according to financing and managing models followed (public, private, or public-private partnership), ownership, operator and operational model, scale and range (Bakogiannis , et al., 2018). On the other hand, bike rental is always managed by a private owner and the benefits generated by the service (economical, environmental, social) have a negligible effect on the urban community.

Nowadays bike sharing is a very successful way of transportation. In 2014, the number of cities that operate bike sharing programs increased to 855, with a total of 946.000 bikes in operation (**fig.1**). The most important projects are developed in US, China, Canada, Europe and Australia where the majority of scientific researchers operate too. (SI et al. 2018). Especially in China a real boom has occurred in the last few years, making it the most important market in the world for this mean of transportation at present date.

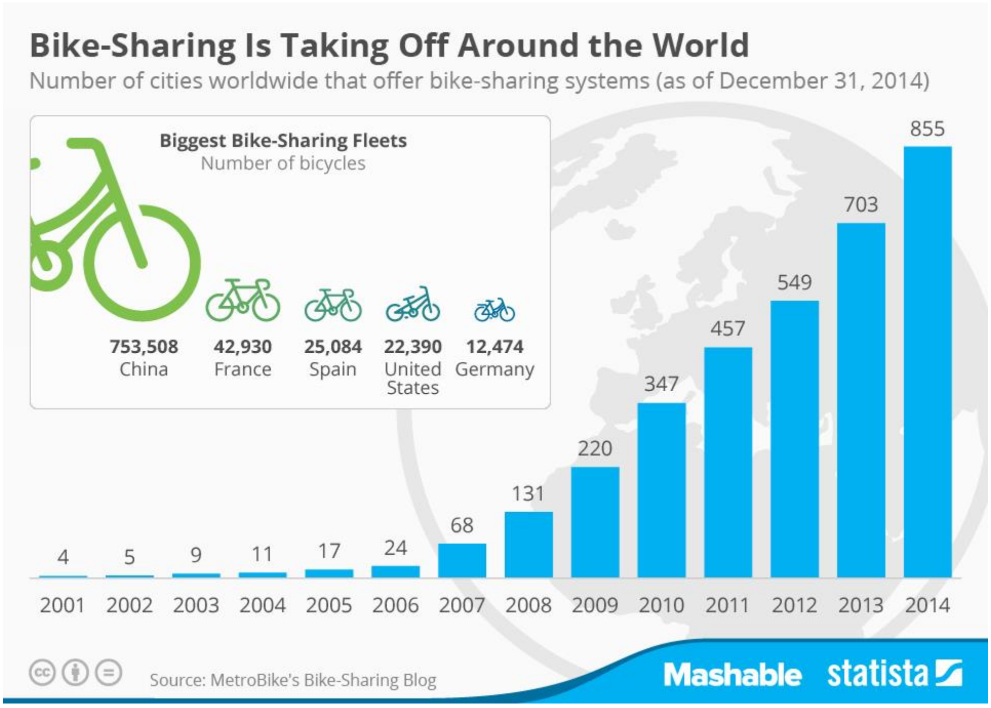

Figure 1. Bike sharing world data (source: https://www.statista.com/chart/3325/bike-sharing-systems-worldwide/)

2. BIKE SHARING EVOLUTION

Notwithstanding the recent worldwide spreading trend of this transportation alternative, the first trials started in Netherlands in 1965, followed by a general technological and operational effort to implement evolutions. It is possible to detect five different generations in bike sharing systems.

1. The 1st generation was developed in Amsterdam in 1965. This program provided fifty ordinary painted white bikes, known as "White bikes", that were left to free use in different city locations (Zhu, 2018). Every user could find a vehicle, ride it to his destination, and leave it for the next following user. Things did not go as planned, as bikes were thrown into the canals or appropriated for private use. This is why the program collapsed within days (De Maio, 2009). Other similar programs were developed in other cities, but each one experimented issues such as burglaries, vandalism and lack of incentives for returning the bicycles in original conditions.
2. The 2nd generation was introduced in some Danish cities (Farso, Grena, Naskov) during the 90s. A substantial improvement with respect to the former ones was a coin-deposit system to unlock the bicycles. Specific stations were used, in which every bike could be left and locked by the users after their ride. The most important application for this model was in Copenhagen (Byciclen) in 1995, where a large-scale bike sharing system was created. Over 1,100 specially designed vehicles characterized by solid rubber tires and wheels with advertising plates were bought which could be picked up and returned to specific locations throughout the central city with a coin deposit. A small amount of money was necessary to unlock the vehicle which was refunded on bicycle return (Shaneen, et al., 2010). Even if this system was definitely better if compared to the first one, some problems still remained, especially connected with the absence of time limits for bike use. Many vehicles were borrowed for long times or never returned. However, many cities all over Europe and North America created bike sharing programs using this kind of technology and this was a very important step for following developments (Zhu, 2018).
3. The 3rd generation systems (**fig.2**) based their success on the use of technological improvements, including electronically-locking racks or bike locks, telecommunication systems, smartcards and fobs, mobile phone access, and on-board computers (De Maio, 2009). This massive use of new technologies gave also the name to these programs, that were identified as "Smart Bikes Programs" or "IT-Based System" (Zhu, 2018). These were the first models that gained worldwide

popularity and forced many researchers to focus their studies on this topic (Shaneen, et al., 2010), (Fishman, et al., 2013). The four main components of third-generation bike sharing programs are (a) distinguishable bicycles (either by colour, special design, or advertisement); (b) docking stations; (c) kiosk or user interface technology for check-in and checkout; and (d) advanced technology (e.g., magnetic striped card, smartcards) (Shaneen, et al., 2010). All these elements permit to reach a higher level of security and provide also a good way to track the vehicles during their trips. This is very important in order to prevent thefts but also to collect information on users' habits and plan a more efficient logistical organization. The most important 3^{rd} generation programs were launched in some French cities (Lyon, La Rochelle, Paris etc…) between 2005 and 2007 with significant results (Zhu, 2018). In particular in Paris the Vélib program represented an enormous success with more or less 20,000 bikes in 2009 (Midgley, 2009); this program became a model for many other European cities and remained for many years the biggest bike sharing scheme in the world (Zhu, 2018).

Figure 2. Bike sharing system Yélo La Rochelle (source: http://www.eltis.org/discover/case-studies/bike-sharing-system-la-rochelle-france)

4. The 4^{th} generation models were strongly based on the 3^{rd} ones and represent their natural technological evolution. In fact, there aren't many showy differences between this kind of bikes and the more advanced ones of the 3^{rd} generation (Zhu, 2018). The main goal of the new improved technologies is the creation of a "demand-responsive, multi-modal system" (Shaneen, et al., 2010) This aim is pursued by emphasizing the creation of flexible, clean docking stations; developing bicycle redistribution innovations; using smartcard integrated with other transportation modes,

such as public transit and car sharing; and adopting technological advances including Global Positioning System (GPS) for tracking, touch screen kiosks, and electric bikes. (Shaneen, et al., 2010).

5. The newest innovation in bike sharing models is represented by the dock-less models (**fig. 3**) that were developed for the first time in China during 2016. Some authors (Si, et al., 2019) classify them in a new group, the so called 5th generation. These systems represent a drastic revolution with respect to the previous models, because they maximize the use of new technology and eliminate the docking stations at the same time. Users can return the bicycles everywhere resolving the stations' availability issue (Zhu, 2018). These programs are literally experiencing a general boom in many cities all over the world (Si, et al., 2019). Nowadays the majority of active projects all over the world can be classified as 4th or 5th generation systems. The two different models (dock stations vs free flow) have been developing alongside each other.

Figure 3. Pilot dock less bike sharing system in the USA (source: https://bike4trade.sport-press.it/2018/06/04/bike-sharing-gli-usa-inseguono-la-cina/)

In order to identify the different features of every generation, a table is provided (**tab. 1**) to summarize all the most important features.

	1st generation	2nd generation	3rd generation	4th generation	5th generation
COMPONENTS					
BICYCLES	X	X	X	X	X
DOCKING STATIONS	X	X	X	X	
KIOSK AND USERS INTERFACE TECHNOLOGY			X	X	
BYCICLE DISTRIBUTION SYSTEM				X	
CHARACTERISTCS					
DISTINCT BICYCLES (COLORS OR SPECIAL DESIGN)	X	X	X	X	X
FREE BYCICLES LOCATION	X				X
BICYCLES UNLOCKED	X				
NO CHARGE FOR USE	X				
PICK UP AND DROP OFF AT SPECIFIC STATIONS		X	X	X	
BICYCLES LOCKED		X	X	X	X
USE OF SMART TECHNOLOGIES FOR CHECK IN/OUT			X	X	X
THEFT DETERRENTS/USERS IDENTIFICATION			X	X	X
PROGRAMS PAID FOR AS A MEMBERSHIP SERVICE			X	X	X
MOBILE DOCKING STATIONS				X	
CLEAN ENERGY POWERED DOCKING STATION				X	
USE OF MULTI MODAL SMART CARD				X	

Table 1. Bike sharing systems' classification (source: Author elaboration)

3. E-BIKE SHARING

One of the most interesting development experienced by the newest bike sharing generations (4th and 5th), is the adoption of electric bikes as vehicles to share. Furthermore, we could say that this new technology has emerged in parallel with the rising popularity of bike sharing (**fig. 4**) (Ji, et al., 2013).

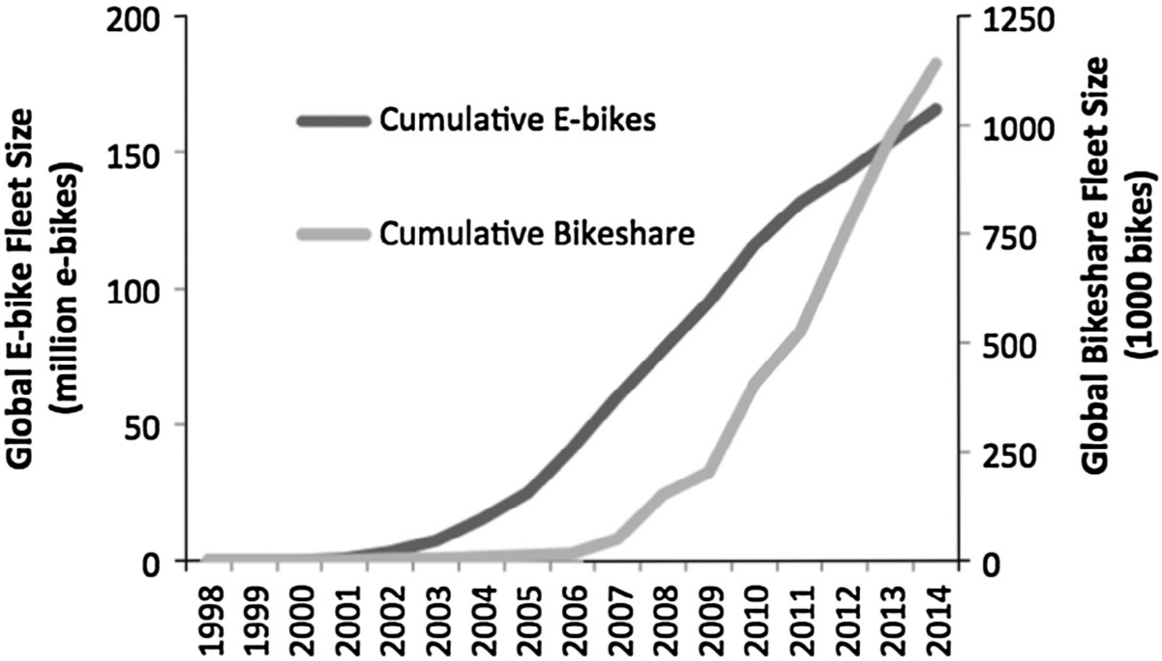

Figure 4. Growth in personal e-bike and public bike share systems (source: (Campbell, et al., 2016))

Reborn in China in the past decade, electric bike technology has evolved and over 100 million samples have been sold since the early 2000's (Cherry, et al., 2010). Electric bikes, namely power-assisted electric bikes, appear and operate much like traditional bicycles (**fig. 5**). Power-assisted electric bikes require the rider to pedal while an on-board control technology assists the rider by supplementing his effort with electromechanical power. The power assistance is guaranteed until a 25 kph speed is reached. This effectively increases the range of the bike and reduces fatigue barriers, particularly in hilly terrain. However, the Li-Ion batteries and all the other components made e-bikes normally heavier than the traditional ones (20-25 kg vs 11-15).

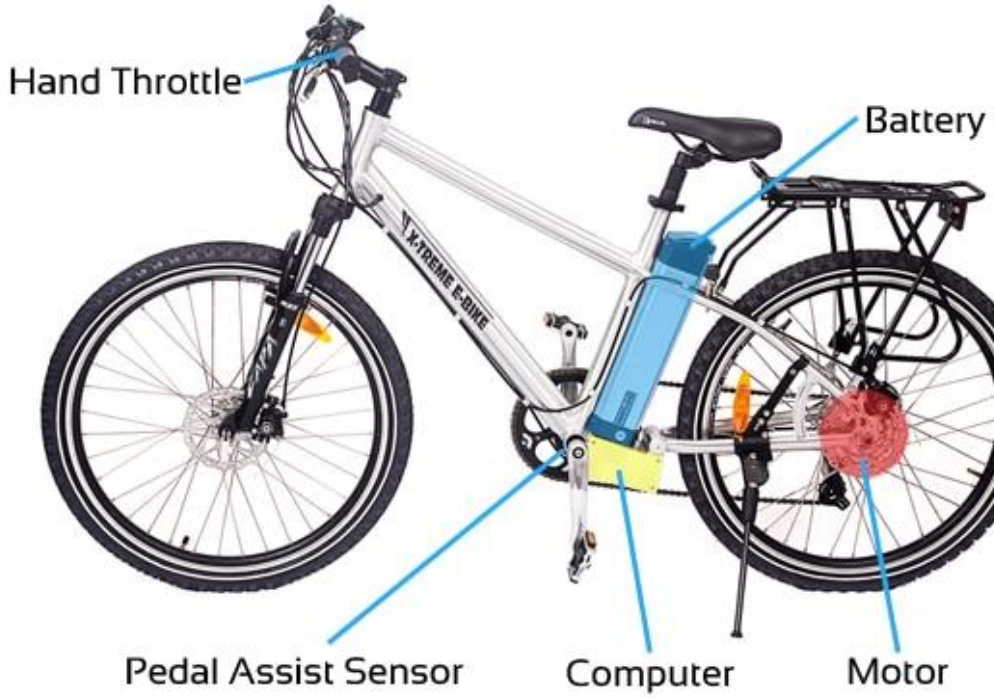

Figure 5. Typical pedal e-bike and its components (source: https://www.farbike.com/blogging/what-is-an-electric-bike-the-basics/)

The benefits listed before make electric bikes more attractive to casual riders, who might otherwise avoid traditional bicycles (Cherry, et al., 2010). Indeed, some of the goals of bike sharing include attracting casual bike riders. Much of the commuter market is not pre-disposed to commuting by bike for a number of reasons. Electric bikes can overcome some barriers to bicycling for viable, expanded market of commuters. However, electric bikes are generally significantly more expensive than similar quality non-electric bicycles. Sharing electric bikes can overcome price barriers by spreading the cost over many users. Including electric bikes in a shared environment also casually introduces the technology to users without the pressure or commitment of a purchase. Many of the operations of an electric bike sharing system are similar to those of traditional ones. A typical electric bicycle sharing system consists of bicycles, a vending and charging station, and support system (**fig. 6**) (Cherry, et al., 2010).

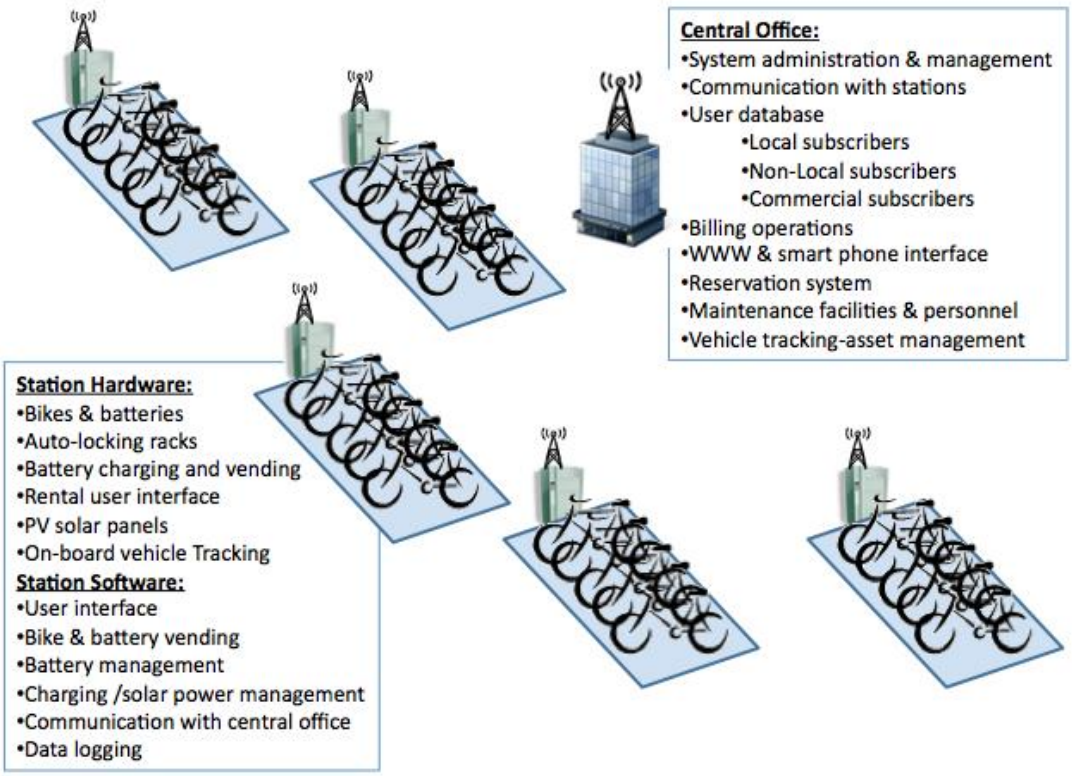

Figure 6. System Components of Electric Bike System (source: (Cherry, et al., 2010)

It's possible to resume the main challenges involved with e-bike sharing (Cherry, et al., 2010), (Ji, et al., 2013), (Campbell, et al., 2016) :

1. Electric bikes are effective hybrid vehicles (i.e., if the battery dies, the rider can still pedal the bike to his or her destination, but with a really significant effort). So it's very important to verify that an effective electric bike sharing system could ensure that the user of the system has a maximum amount of range available. Since most electric bikes have a range that is below the demand demonstrated by many shared bike systems, it is possible that range will diminish over the day.
2. Recharging is also a big issue in a shared environment because of the long time needed for this process. Electric bike sharing systems have to develop electrical connections that are safe and automatic (rather than relying upon the user to manually plug in the vehicle). In some pilots a distinct recharge for batteries removed from the vehicles was planned (**fig. 7**). This is a good solution because it allows all available bicycles to remain in service while the battery is recharged

if there are more batteries than bicycles in the system. In these projects a reliable and physical secure battery management system to store them during recharging time was necessary.

3. The cost theme is also quite critical. Electric vehicles are more expensive than the traditional ones (with a retail value of more than 1,900€) and this makes theft reduction, asset management, and appropriate business model development more important than traditional bike sharing services. Moreover, extra costs are required for building stations connected with electric utility or powered by a solar-based system. This solution seems to be the cheapest and the most promising one, even if it's important to connect the infrastructure with an alternative energy supply source. In fact, enough reserve energy capacity must be provided to ensure uninterrupted service in periods of inclement weather.

Figure 7. System components of e-bike sharing system

In order to resume positive aspects and critical issues related with e-bike sharing services, a summary table was produced (**tab.2**) in order to list all the main aspects shown before.

POSITIVE ASPECTS	CRITICAL ISSUES
Suitable for elderly people or casual riders (less effort required)	More expensive vehicles
Faster vehicles	Heavier vehicles
Larger utilization range	Higher speed reached (can increase the number of accidents)
Suitable for challenging terrains (hilly or mountainous ones)	Electric recharge points needed
	Higher energy demand
	Higher investments required

Table 2. Qualitative comparison between positive and negative aspects of e-bike sharing (source: Author elaboration)

Some e-bike sharing pilots were developed during the last few years all around the World. One of the most successful (the so-called Cycle Ushare) was implemented by the University of Tennessee in its campus located in Knoxville (**fig. 8**). In this area two different stations were built and 14 electric bikes made available for students, faculty and staff. One of the stations is totally solar powered. Participating users can access the bikes for up to four hours at a time for free. This is why this was developed as a research project.

Figure 8. Solar powered station at the Knoxville campus (source: http://cycleushare.utk.edu/cycleushare/E-Bike_Sharing_at_UTK.html)

Big cities as well are trying to join the benefits generated by electric bikes use. In 2016 an e-bike sharing service (biciMAD) was launched in Madrid (Spain). More than 2,000 vehicles and 165 stations formed one of the biggest bike-sharing network around the world. Both tourists and residents can join the service through different subscriptions programs and fees.

4. BIKE SHARING IMPACTS

The use of bike as a transportation solution in urban contexts is universally recognized as positive, especially for the absence of polluting emissions, the reduction of urban congestion and the improvements of users' health. Cycling thus has strategic importance for the sustainable development of the cities (Bakogiannis, et al., 2016) and has become one of the fundamental parts of every city mobility strategy. All the benefits are obviously shared by bike sharing which can improve and enhance the effects generated by the private use of these sustainable vehicles. In fact some authors (De Maio, 2009) have noticed that bike sharing programs are able to create a larger cycling population, raising bike mode share between 1.0 - 1.5% in cities with pre-existing low cycling use. Thus, the presence of a bike sharing program acts as a catalyst on the urban population, encouraging people to change their transportation habits. Furthermore, the establishment of bike share programs has prominently enabled cities to demonstrate their commitment to addressing climate change, population health issues, traffic congestion, oil dependence and liveability (Fishman, et al., 2013). According to (Shaneen, et al., 2010), some of the major benefits related to the use of this way of transportation are:

- flexible mobility;
- emission reductions;
- individual financial savings;
- reduced congestion and fuel use;
- support to multimodal transportation connections, by acting as a "last mile" connection to public transportation;
- health benefits.

The health benefits are related to the physical activity connected with biking in general, since a lack of physical activity is associated with many of the leading causes of death, chronic diseases and disability (Hentz Leister, et al., 2018). Increasing the modal share of walking and cycling enhances physical and mental health. At the same time a strong reduction of the number of cars circulating in the cities can decrease the accident rate as well as their consequences. It has been demonstrated that the benefits of choosing cycle in terms of life expectancy are 20 times higher than the injury risks incurred by that choice. So, it's possible to state that higher proportions of commuter cyclists are linked with lower risks of casualties (Bakogiannis, et al., 2016). Bike sharing provides also a low-carbon solution to the "last mile" problem, playing an important role in bridging the gap among the existing transportation networks. Users are encouraged to use multiple transportation modes, in order to reach their final destinations without using private motorised vehicles (Shaneen, et al., 2010). SmartBike (Washington, D.C.), for instance, estimates that more than 50,000 trips made with their vehicles cover a total of 200,000 km per day, saving more or less 37,000 kg of carbon dioxide (CO_2) emissions per day (Fishman, et al., 2013). So we can say that bike sharing can reach tangible results on emissions savings and congestion reduction only by expanding and integrating cycling into transportation systems, in order to make it a daily transportation mode (Shaneen, et al., 2010). Users often choose this modal as part of a trip chain and usually the creation of a bike sharing system generates substitution from public transportation towards this new system since it's perceived as a more efficient and smart way of transportation capable to overcome some obstacles as well. Despite that, every administration interested in improving bike sharing should take into account that there are many barriers that could hinder the growth and the development of this program. The first element that users usually perceive as very limiting is the lack of biking infrastructures, followed by the absence of knowledge about how to use bike share (Hentz Leister, et al., 2018). These are two of the most important issues that need to be fixed in order to facilitate bike sharing. In general, the most critical aspects that operators have to manage to satisfy users' necessities are (AIT / FIA Information Centre (OTA), 2012):

- wide kiosks' network creation, with a suitable number of vehicles;
- strong integration with Public Local Transportation network, locating kiosks close to the bus/train station and unifying the tickets system;
- forecast different kinds of users' necessities (locals and visitors), providing tailored fares and payment solutions, without excluding any category from the possibility to access the service;
- keep cost-effective fares with the purpose of favouring modal shift from private vehicles and attract new users;
- guarantee a good communication service which provides all the useful information as well as an efficient user's assistance;
- easy bikes' drop off, eventually out of the planned stations if there are no place available;
- provide safe, comfortable and durable vehicles, taking into account the different mobility necessities;
- plan efficient solutions to deal with some typical bike sharing problems as vandalism and bike redistribution (both for traditional and dock less systems).

Deeper evaluation by authorities and planners is needed on whether electric bikes shall be included in the integrated transport scheme or not, by taking into account, for example, the vehicles' range and their charge times. Specific recharging points have to be created.

All the system's elements need to be well designed in order to have an efficient bike sharing service capable of issuing basic but fundamental principles as autonomy, ease of utilization, user safety and equipment security (Bakogiannis, et al., 2016). Financial autonomy is, finally, the most critical objective to score. Many past projects have failed or needed to be improved mainly from the financial profitability side (Sun, et al., 2018). The conflict between low fares (necessary to attract new users and guarantee an accessible public service) and high costs (due to vehicles and stations' maintenance, operating costs, bikes' redistribution etc...) shall be solved by the help of well-planned advertising and other forms of self-funding initiatives (Shaneen, et al., 2010).

5. BIKE SHARING IN ITALY AND CROATIA

Italian people are moving towards a more effective bike use; even if they are mostly still oriented to private car utilization, bike as alternative way of transport is growing slowly but constantly. The modal share data, especially in medium-sized towns as Pesaro and Bolzano, show that a significant groups of citizen have changed their transport habits in the last few years (Legambiente Italia, 2017). Even in the biggest cities as Milano and Torino bike has become a competitive mobility choice. In this context, we could say that bike sharing is playing an important role in enhancing and promoting bike use. Bike sharing is the most dynamic and significant shared mobility service among the ones currently active in Italy (**fig. 9**). In 2017 bike sharing programs were running in 51 different municipalities with an average value of 220 vehicles and 20 stations. As much as 3,300 persons per day usually enjoy this mobility option using specific passes. This value is strongly influenced by the data referred to the most populated cities (Milano, Torino), where the biggest programs are active (Legambiente Italia, 2017).

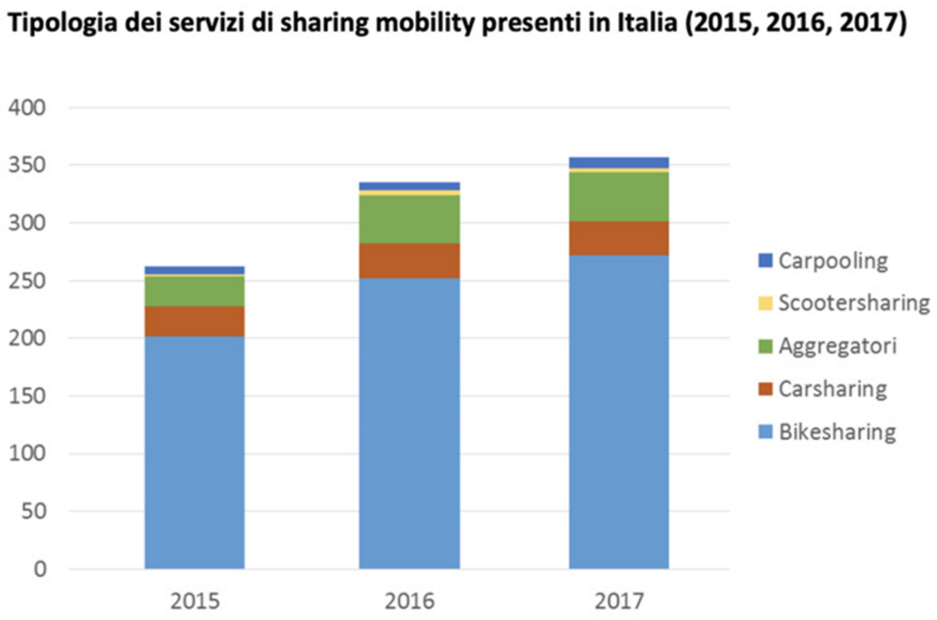

Figure 9. Data from different sharing mobility programs active in Italy (Source: Osservatorio Nazionale Sharing Mobility)

The majority of these programs are managed by municipalities or other public partners and use 3rd or 4th generation station-based systems. However, during 2017, some private operators (Ofo, Mobike, Obike e Goobeebike) started operation in Italy, introducing free floating systems and electric vehicles in some cases in parallel too (Ciuffini, 2018). This produced a real boom, doubling in few weeks the number of vehicles circulating on Italian streets (from 16,000 to 39,000) (**fig. 10**) (**fig. 12**)

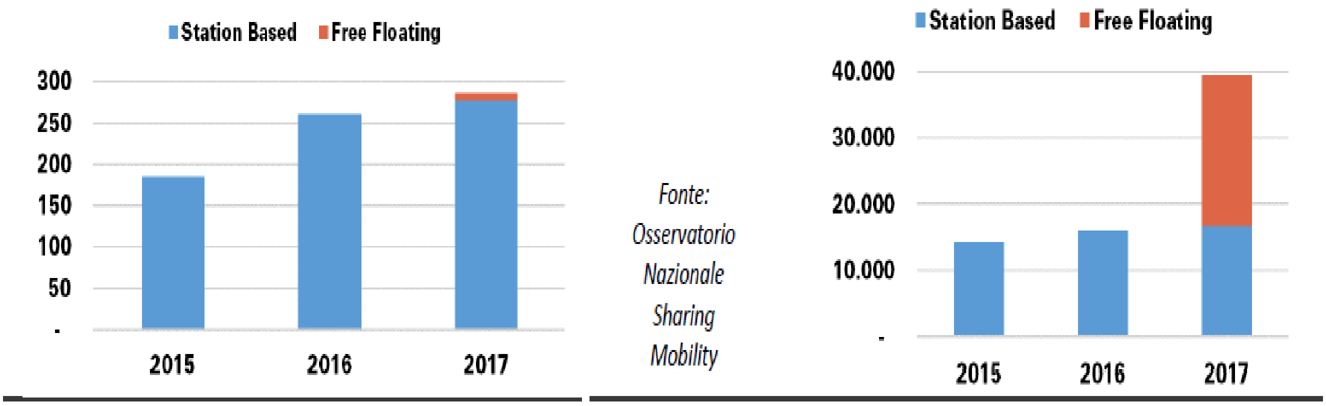

Figure 10. Number of services and bicycles offered by the two kinds of bike sharing systems active in Italy 2015-2017 (Source: Osservatorio Nazionale Sharing Mobility)

Only in the last few years some bike sharing programs have reached Croatia (**fig. 13**). Nowadays most of the active projects are managed by a private company (Nextbike) in some of the biggest cities of the country (as Karlovac, Zagreb, Zadar, Syberik etc…). In Pula an European program (MOVESMART) was launched in 2013; its goal was the creation of a e-bikes' sharing fleet (Bičikleta) that could promote sustainable mobility among citizens. The two-years pilot was successful and now the service is still running. Three different stations are located near some of the local places of interest (central bus station, central market and a popular green area): here 18 electric bikes can be picked up and dropped off, without any time limitation. The service cost for users is very low in order to encourage them to use this new solution.

Figure 11. Bike sharing system in Pola (Source: http://www.pula.hr/hr/novosti/detail/15714/siri-se-mreza-javnih-elektricnih-bicikala-u-puli/)

Figure 12. Map of bike sharing programs developed in Italy (green= actives, blue= under construction, red= failed) (Source: the bike sharing world map, 2019)

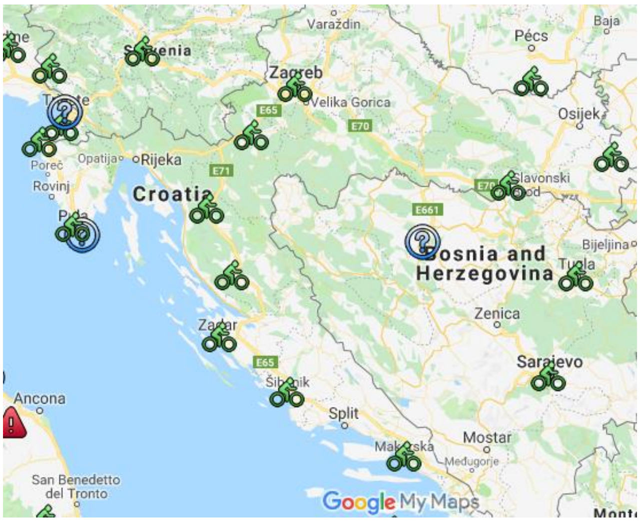

Figure 13. Map of bike sharing programs developed in Croatia (green= actives, blue= under construction, red= failed) (Source: the bike sharing world map, 2019)

6. CRUISE TOURISM

Cruise could be generally defined as a voyage on a ship undertaken wholly for reasons of leisure and recreation (Polat, 2015). Many private companies (cruise companies) organize every year this kind of trips usually starting from North American, European and Chinese ports (**fig.4**), with a variety of different destinations all over the world. Caribbean and the Mediterranean cities account for as much as 55% of the cruise capacity supplied (Rosa-Jiménez, et al., 2018). Nowadays this sector is recognized by many authors as one of the most dynamic, from the point of view of both maritime transportation activities and touristic ones (Rosa-Jiménez, et al., 2018), (Lamers, et al., 2015). Just to mention some figures, in 2011 around 20 million cruise passengers were counted with an annual growth rate of around 7% (Lamers, et al., 2015) (**fig.5**). In parallel, also the number and dimensions of ships dramatically increased; currently the biggest ones are able to carry as much as 6,000 passengers (Perez Hoogkamer, 2013).

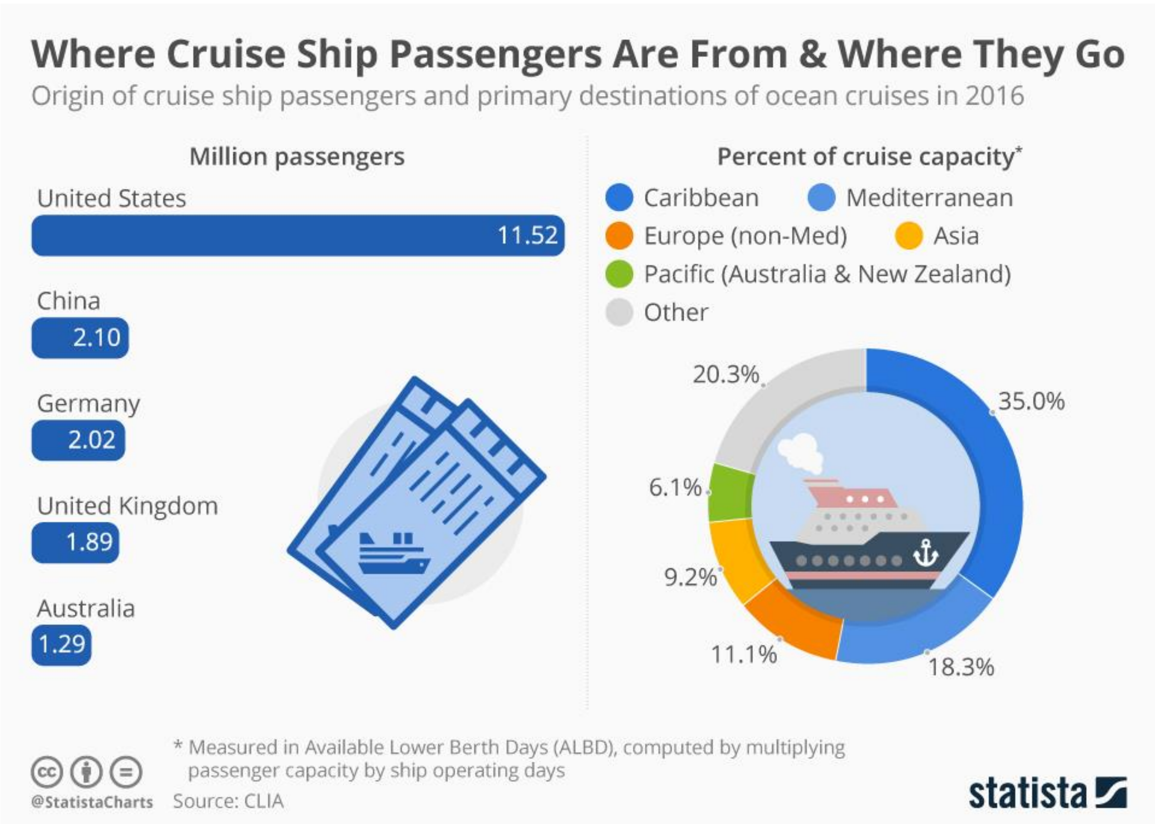

Figure 14. Origin of cruise passengers and their primary destination in 2016 (Source: https://www.statista.com/chart/10994/origin-of-cruise-ship-passengers-and-primary-destination-of-ocean-cruises/)

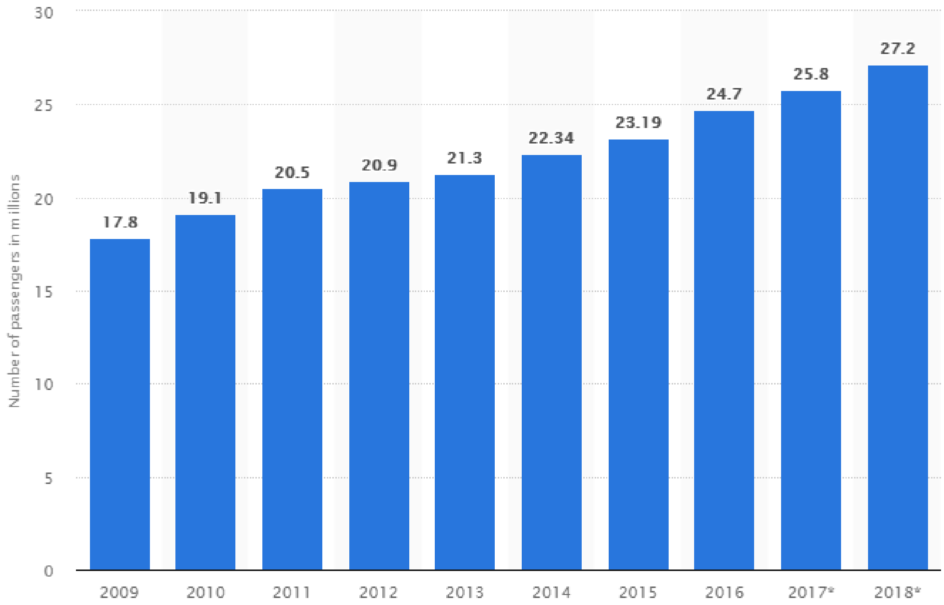

Figure 15. Number of passengers of the cruise industry worldwide from 2009 to 2018 (in millions) (Source: https://www.statista.com/statistics/385445/number-of-passengers-of-the-cruise-industry-worldwide/)

The supply of cruise products has also become more diversified. On the 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, we can find large scale cruises on vessels equivalent to floating cities, operating in established cruise destinations, like the Caribbean, the Mediterranean and Northwest Europe. There are also other activities such as river cruising and boating that have also gained popularity in several regions (Lamers, et al., 2015). This industry is surely facilitating the improvement in the tourism potential, infrastructure, and the social development of a large number of port cities, but it's also producing a negative impact on their maritime, urban, socioeconomic, and environmental resources (Rosa-Jiménez, et al., 2018). 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 big ships' arrival in fragile contexts or in small seaside locations have to be added. Typically, cruises foresee frequent stops in different locations, in which tourists can spend only few hours visiting the place and doing shopping. Many authors (Rosa-Jiménez, et al., 2018), (Polat, 2015), (MacNeill & Wozniak, 2018) have demonstrated that the benefits derived from this kind of tourism, hospitality and transportation model are usually marginal compared to the "social costs" generated, which can be up to seven times larger than the economic ones. Thus, it is very important to try to develop sustainable solutions in order to mitigate the strong impact generated by the arrival of many cruises in seaside locations, with particular reference to the transfer mode from the ship to the city centre or other touristic attractions. Traditionally, trolleybus or other motorised vehicles are used for this purpose. Offering alternative transportation services, bikes for example, could be an interesting but challenging solution, where sustainable behaviour of some cruiser is faced by the low familiarity with the place and the reduced comfort of the displacement.

Both the two countries involved in this study (Italy and Croatia) are very popular cruise destination. If we consider the Mediterranean D500 (ports cruise destinations which exceed or equal 500,000 passengers per year) we can find seven Italian ports (Bari, Civitavecchia, Genoa, Leghorn, Naples, Savona, Venice) and also a Croatian one (Dubrovnik). (Rosa-Jiménez, et al., 2018) All these locations are reached by big tourists' groups that have a very strong impact especially in the smallest centre as Dubrovnik or Venice, furthermore characterised by small streets or fragile environmental conditions.

7. NAUTIC TOURISM

Marinas are small ports that are mostly used for leisure purposes, often surrounded by tourist facilities (CAMBRIDGE). These infrastructures are usually built in natural bays or coastal lagoons and have essentially a recreational use. Private boats' owners can get access and find many useful services as refuelling, washing and repair facilities, marine and boat chandlers, stores and restaurants. A marina may include ground facilities such as parking lots for vehicles and boat trailers. The main difference between a cruise port and a tourist one is that in the latter ones it's impossible to handle large passenger ships or cargo from freighters. This is why the services provided and the demand insisting on those two infrastructures will be completely different: marinas are mostly characterised by small, seasonal travellers flows. In particular it's possible to identify at least three different tourist segments with their special needs (Musolino, et al., 2019): stationary users, with boats permanently moored at a port; seasonal users, with boats moored at a port in some periods of the year; in-transit users, that occasionally use port infrastructures and services. All these people are usually forced to use the private transport to reach the port or to leave it: in fact the scarce transport demand often doesn't permit to create dedicated public transport lines. Stationary and seasonal users reach the port from land using private or public transport modes. In-transit users reach the port from the sea by boats. This class could use land infrastructures and mobility services to carry out activities (e.g. for leisure) in the area close to the port (Musolino, et al., 2019). Offering a proper bike share system could be a good solution to deal with this mobility problem; boats owners and their passengers use to be dynamic and independent people that could be very enthusiastic to try this new mean of transport. In addition to this, they could use the marina as a starting point to discover the nearest towns and the other attractions (beaches, monuments, natural areas). Both Italia and Croatia are very important market for the leisure port tourism; lots of marinas are located on the both side of the Adriatic Sea (**fig. 13&14**). This is way this segment seems to be the most promising to promote new ideas related with bike sharing systems for tourism.

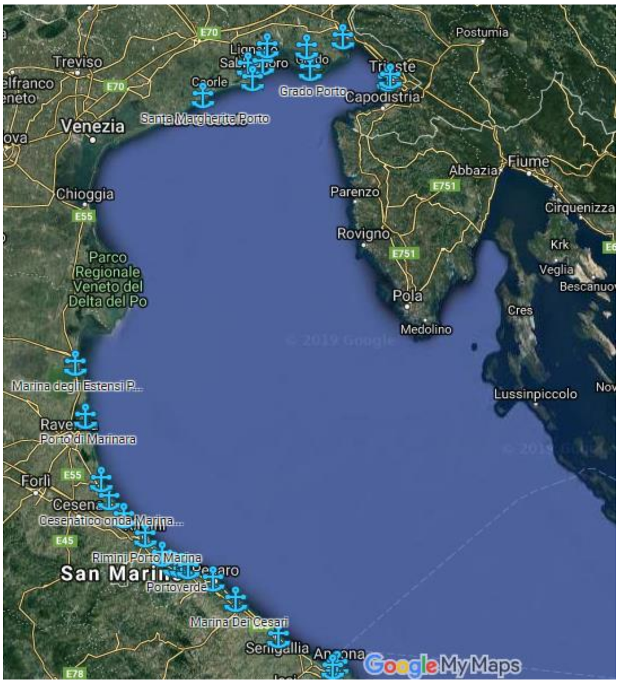

Figure 16. North Adriatic Italian marinas (Source: http://www.portiditalia.it/porti/mappa-dei-porti-turistici-italiani/)

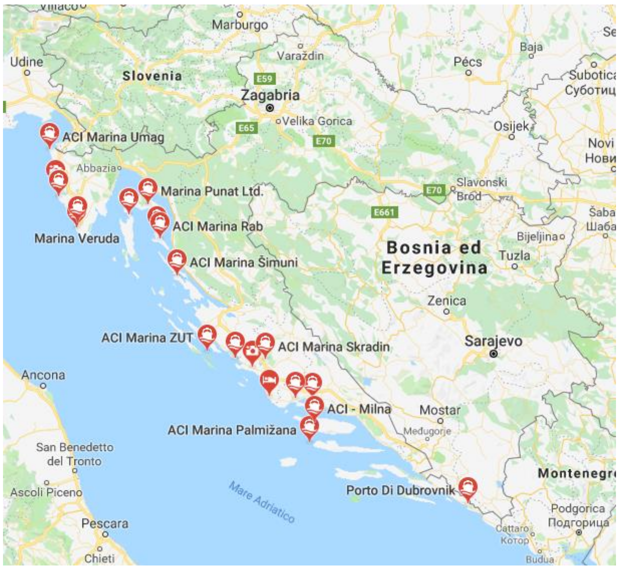

Figure 17. Most important Croatian marinas (Source: Google maps)

8. BIKE TOURISM

The 20th century tourism has become one of the major sources of income for many cities and townships. The relationship between tourism and transportation development is inseparable and a balanced development of both this aspects affects local economy, nation-wide and international competitiveness in many countries (Chang & Chang, 2003). We can define bike tourism using some general features, useful to identify it in a better way (Han, et al., 2017):

- Users are away from home;
- The duration can vary from a single day to several days;
- Non-competitive;
- Cycling should be the main purpose;
- Occurs in an active context;
- Recreation/leisure form.

However, bicycle tourism 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 the total holidays (Kaplan, et al., 2015). Nowadays this share is growing fast, especially in countries characterized by a strong bike-oriented tradition as the Scandinavian ones. Biking has become the preferred leisure activity of many other groups of the population because it makes it possible to enjoy more authentic experiences connected with nature and culture that would not be available travelling by car (Steinbach, 1995). Bike tourism could also be split in two different sectors: cycle holidays, where cycling is the main purpose (usually in rural or natural regions) and holiday cycling, in which the occasional use of the bicycle has been chosen as an alternative mode of transportation for exploring a destination (Kaplan, et al., 2015). Both have been growing a lot in the last few years in according to the increased environmental consciousness that have pushed many people towards more sustainable choices, also in their recreation and tourism activities (Chang & Chang, 2003).

9. BIKE SHARING FOR TOURISM

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 maximised in cities with a good level of infrastructure as segregated bike paths and routes with low traffic volumes dedicated to leisure activities (Kaplan, et al., 2015). A research carried out in Copenhagen (Kaplan, et al., 2015) has demonstrated that 67% of the persons interviewed had visited a cycling-friendly city at least once or twice before. It was also possible to determine that this mean of transportation was enjoyed both by persons coming from cycling-oriented countries (that may use it as an habit) and from non-cycling countries (that could have the possibility to experience a new activity). Thus, we can say that an efficient bike sharing system is one of the most requested and valued service by travellers nowadays.

At the same time, the presence of an effective bike sharing service can make the city more attractive and easy to visit, strongly motivating tourists to choose it as a holiday destination (Bakogiannis , et al., 2018). Bike trip can also become an integral part of the touristic experience (Kaplan, et al., 2015) with positive effects on its business model too. In fact, tourists using bike sharing could enhance both the financial and environmental performances of the service, helping to reach a positive revenue-expense ratio (Bakogiannis , et al., 2018). At the same time, the positive effects on the urban environment (reduction of pollution and congestion rates etc…), will contribute to make cities more liveable and enjoyable, with positive effects on tourism too. In order to reach this goal, it is necessary to implement some actions:

- Creation of cycling infrastructures → extending and building new bicycle lanes, as well as bicycle stands and parks will enable tourists and city dwellers to increase the share of bicycle transportation in urban tourism (Roman & Roman, 2014). Usually these measures support both residents and tourists, even if a bike sharing service oriented towards tourism could be more focused on recreational paths located in parks or other leisure zones.
- Fair tariff plan for both residents and tourists → frequent users need annual subscription programs or other long term fares, eventually with premium time packages issued for free. Instead, tourists would prefer short term passes, without constraints related to usage time or distance covered. In many cases, the use of bike sharing for tourists is not still diffused due to the difficulty to access the service for a temporary user typology as tourist is (La Rocca, 2015). So the best solution may be the creation of different options, in order to satisfy the different needs. According to (Cavallaro, et al., 2017) the most efficient and cheapest way to promote the use of

a specific mean of transportation is to develop policies that involve tickets and fees, connecting them with all the other transportation options within the city (integrated cards).

- Advertisement → an important issue that planners have to deal with. Tourists need to know how the system works and how it's possible to join it. Moreover, specific norms and limitation (compulsory use of helmet, age limitation etc…) could be clearly communicated (La Rocca, 2015). Every information could be provided not only in mother-tongue, but also in English and in other languages.

10.BIKE SHARING MOBILE DEPOT

This literature review has shown that there many different solutions related with the use of share bikes. This variety is justified by the different focus adopted by every system. The main differences are referred to the target users (commuters, tourists etc.), the business models (public, private), the types of vehicles (traditional bikes or electric ones) and the project sizes (municipal programs, private pilots etc…). In order to classify the different systems we have identified three main categories at which we can refer all the analyzed cases:

1. **Station-Based bike sharing systems**.

   These were developed first (cfr. with chapter 2 "Bike Sharing Evolution") and are one of the most popular ones. They are usually adopted by many public projects because of their safety and strength. The stations, spread in a wide area, could serve a high number of users. By the way they need large free spaces and high investments to build them.
2. **Free Floating bike sharing systems**.

   Many private companies have launched in the last few years this kind of projects, that could represent a cheaper alternative to the traditional ones. The strong point is the possibility to take and drop a bike everywhere in the service area, without using base stations. A good technological level is required because every operation (locking/unlocking vehicles, payment, dropping off etc…) is managed remote by users' technological devices through mobile applications. However the vehicles' relocation represents a big problem that can cause significant extra costs.
3. **Bike Rental**

   The private companies involved in bike rental usually operate in touristic locations and offered a leisure oriented service. Only one base station is required. High fares and scarce use flexibility are the main limitations of this kind of service. In addition they can't work during off-season period, where the number of tourists is very low (or even absent).

Mixing all the strongest aspects of each categories, we have developed a mixed solution that could be ideal for touristic locations, with a seasonal and discontinuous touristic flow. A Bike sharing Mobile Depot could be an ideal compromise between all these aspects. Trying to represent this idea in a graphic way we could say that Mobile Depot is the center of a triangle, where every vertex is occupied by one of the systems listed before (**fig. 19**).

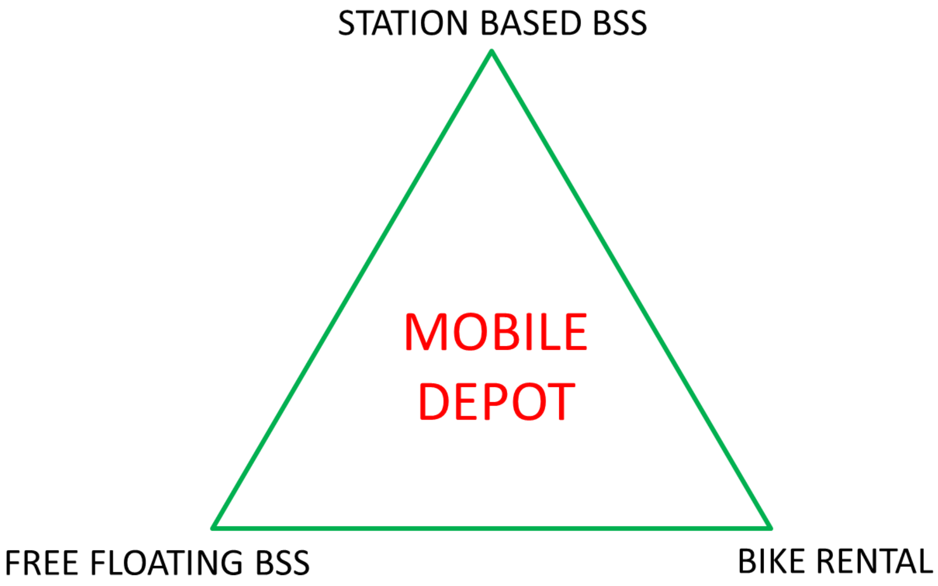

Figure 18. Conceptual representation of Mobile Depot idea (personal elaboration)

Even if a peer review was driven, it wasn't possible to identify many case studies in which a mobile structure was equipped to be use as a hub for a bike sharing system. The scientific literature is mostly still concentrated on commuters-oriented services and seems to neglect the touristic potential of BSS. Only the behavioral aspects behind touristic bike sharing have been investigated deeply by some authors (Kaplan, et al., 2015), (Han, et al., 2017). However, two interesting pilots developed in Valencia and in the USA were presented below. They currently represented the only well documented projects of Bike Sharing Mobile Depot that it was possible to identify. For Quikbyke project the information were mostly provided by the company's website. For the Valencia case it was also possible to get in touch with one of the project's chief, that illustrated the main features of the pilot and the reasons why it was not converted in a regular service (Navarro Correcher, 2019).

11. VALENCIA CASE STUDY

Valencia (790.000 inhabitants) is the third Spanish city for population and one of the biggest industrial and commercial harbours in the Mediterranean area. Favoured by the touristic vocation of the city centre and the good level of maritime infrastructures, the cruise sector is quickly growing up; during the last year (2018) more or less 400.000 cruise passengers reached the city. However the total port capacity has not yet been reached, so the Port Authority and the Local Touristic Centre are trying to adopt new strategies to make the city more and more attractive. At the same time any new solution implemented to facilitate disembarked passengers' mobility has to comply to sustainable standards. For example, during the last year, a pilot project has been launched, in order to provide tourists with an alternative solution to reach the city centre (6.5 km far from the port). Normally people used to get off and take immediately a bus to reach the city centre: during the six-month duration test, the Port Authority provided a bike depot with 10 electric bikes that could be rented by cruisers who would be interested to discover Valencia in a different way. In particular, the main target was focused on younger people (25-45 years) and more dynamic elders, that were supposed to be more used to this kind of vehicles. The main components of the service were:

- An automatic depot, where the bike could be picked up and dropped off only using a specific app. No human assistance was required even if a person was always present every time a cruise ship arrived to greet tourists and show how the service worked. Another depot located in the Valencia city centre and managed by another company was also available for temporary bikes' drop off.

Figure 19. Automatic bike depot (from https://sumport.interreg-med.eu/pilot-actions/e-bike-sharing-in-valencia/)

- 10 electric bikes produced by KYMCO (Q-LITE model), equipped with a smart locker with GPS system integrated.
- Solar panels, necessary to run the depot and recharge the vehicles' batteries (in more or less 4 hours).
- A specific app used for vehicles' reservation.

Caracteristicas de la Bicicleta Eléctrica marca KYMCO, modelo: Q Lite	
Cuadro:	Aluminio
Ruedas:	Llantas de aluminio y neumáticos Kenda K905, 24*1,95 con banda reflectante
Motor:	Biactron - trasero, 250 W / 44v - 340 r. p. m.
Par Máximo:	38 Nm
Sonoridad:	<50 dB
Batería:	Litio de 360Wh (autonomía 90 Km calculada en usuarios de 75 Kg.
Peso Batería:	2,7 Kg.
Tiempo de carga:	4,1 h (0% al 100% de capacidad)
Suspensión delantera:	Rigida
Suspensión trasera:	Amortiguador con ajuste de precarga en 7 posiciones
Frenos hidráulicos Tektro (O):	Discos de 160 mm
Sensor de par:	Idbike TMM4
Sensor de velocidad:	King-Meter FH
Cadena:	Toya Deca 101
Peso (con batería)	22 kg.
Carga máxima soportable:	100 kg.
Iluminación delantera LED:	AXA Blueline 30
Iluminación trasera LED:	AXA GO
Pedales:	Wego F178DU pligables con el pie
Display:	LED, extraíble y retro iluminado. Botones de encendido y apagado, bloqueo y turbo; testigos de niveles de ayuda y batería. Información de la velocidad, cuenta kilómetros total y parcial, y autonomía restante.
Colores	Ehite Lux, Black Umbra y Red Vita

Table 3. E-bikes technical features of the Valencia case study bikes

The service was funded by the EU through the INTERREG projects SUMPORT (75%) and by the Valencia Port Foundation (25%). The total investment necessary to start the project was 8,000 €. The pricing policy was established in order to favour one day rental. However, it was also possible to take the vehicles for only one or two hours with a little economic saving.

Figure 20. Price policy

A good advertising campaign was launched, using different media channels: periodic Media campaign, interviews, press releases, brochures, kiosk inside the cruise and in the Valencia port were made available. Even the tourist bureau inside the Valencia port was involved and there was always an employee to greet people, promote the service and provide assistance.

Even though the service was efficient and well-advertised, the results at the end of the pilot were very disappointing. Only eight persons rented a bike, even if many free rides were offered. It wasn't possible to reach a deal with cruise companies because they usually offer transfer service included to their passengers. Tourists can buy the tickets for these services directly on-board, so only very few people arrived in Valencia without a plan. Many cruise companies use to offer private bicycles to rent too and therefore they were not interested in joining the pilot. Although all these problems stopped any future development of this project, some aspects are worth attention, such as the possibility to provide solar recharge to an automatic depot. Many important aspects related with frequent vehicles' use (robberies, mechanical failures etc…) were not considered because of the very low number of trips done. There are no evidences if an efficient plan to face these problems would be prepared.

12. QUIKBIKE (USA) CASE STUDY

Quikbyke is one of the few successful cases of mobile hub equipped for bike sharing or rental. It is a private company created in 2015 by Bill Moore; this businessman, well known in the USA for its website E-vehicles, have created this new spin-off society, in order to promote e-bikes use especially in touristic locations. The first prototype developed by Quikbyke during 2016 is Q-Pod (**fig. 22**), a solar-powered electric bicycle rental "shop-in-a-box". Unlike the traditional ones, this shop could be fast removed and placed in another location, in order to satisfy the seasonal travelers' flows. The first trials were installed in Omaha (Nebraska), where it spent summertime in the 2016; during the same year the hub was moved to St. Petersburg (Florida), trying to attract the cruise passengers that every winter arrive there.

Figure 21. Quick Byke Pod on service (from http://quikbyke.com/)

Quikbyke offers an affordable and renewably-powered local transportation option especially for middle-aged people who want to visit touristic places. The system fits inside a side-entry 20-foot shipping container and uses a rooftop solar array to feed a 400Ah lead acid battery bank (**fig. 23**): it charges six electric bikes and provides all of the electricity to run the point-of-sale station, the wireless network, and the interior LED lights, with no external energy inputs. However the system was engineered to be able to double the number of solar panels if needed, so the number of the bicycles could be enhanced. The standard size and self-contained design of the shop makes it easy to handle by ship or truck, and the solar array and battery bank avoid the need for any power hook-ups or other infrastructure once in place (**fig. 24**). Every vehicle is equipped with lithium-ion batteries, that provide between 20-30 miles (40-50 km) of riding range per charge, depending on rider input and local terrain. Even if the fares were quite high ($5 for 30 minute and $5 every extra half hour), especially in comparison with other European systems, the project has reached his business goals and a new expansion phase has been planning. The company is trying to spread this idea through franchising in the Caribbean area, where a lot of cruise companies operate and the environmental conditions seems to be very promising (small and crowded towns, willingness to discover places in a more authentic way etc…).

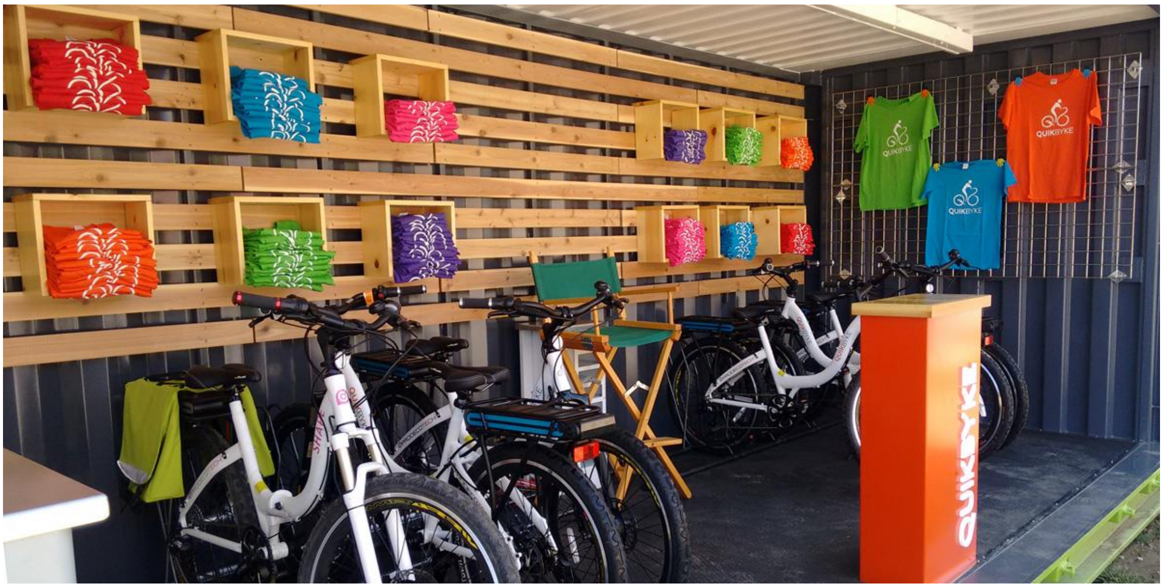

Figure 22. Internal view of a Quick Bike Pod (from http://quikbyke.com/)

Figure 23. Quikbyke in Omaha (Nebraska) (from https://www.trendhunter.com/trends/bike-rental-shop)

PART 2. DETAILED ANALYSIS ON THE MOBILE DEPOT BUSINESS MODEL: TECHNICAL AND ECONOMIC SOLUTIONS

The second part of the report analyse more in deep the technic and economic aspects related to the replicability of the Moses Mobile Depot tested in Ravenna during the pilot activities conducted in the framework of the project.

13. FROM THEORY TO PRACTICE

The transport paradigm prioritizing automobiles over people has been leading for many years in urban settings, resulting in a general drop of bicycle ownership rates since the 1980s. More recently, bicycle tourism emerged from the niche and led industry as well as local authorities to seek strategies to attract bicycle tourists and develop their loyalty, since loyal users are more likely to spend more money. Important drivers of customer loyalty generally involve product/service attributes, perceived value, satisfaction, desire and more recently gender. Bicycle tourism attributes (attractions, accessibility, quality of amenities and complementary services) contribute to the formation of the perceived value of bike activities which in turn influences satisfaction, desire and loyalty. In parallel, environmental concerns, the urge of pursuing sustainability in transport and of preserving health by means of more active lifestyles resulted in policies aiming at promoting the revamping of cycling attitudes. Among the strategies proposed to promote a voluntary travel behaviour change we have bike-sharing, whose importance has become noticeable since late 1990s. Currently, cities are enthusiastic about launching public bike-sharing programs for their perceived environmental and health benefits. However, the challenges of developing a successful bike-sharing program have been frequently disregarded. Despite the almost 2,000 projects and more than 15 million bikes deployed worldwide, history describes also negative aspects and many failures due to financial or operational shortcomings. It is worth pointing out that, besides obvious support by residents, bike sharing is less used. Who is faulting? And how shall a bike-sharing service be designed and managed?

Cycling is being promoted as a travel mode with the capacity to increase sustainable transportation, alleviate environmental problems and support healthier lifestyles. It is viewed as an integral part of any urban mobility policy intervention package looking to increase the quality of life in modern cities and, in particular, bike sharing is a smart mean of promotion of cycling. Addressing the factors underlying the intentions to use bike-sharing systems in cities is important from both the tourism and the transport planning perspectives. Better attitudes toward cycling, interest in bicycle technology, favourable subjective norms toward cycling, and perceived cycling ease have been taken into account. In general, (i) a great interest in using bike-sharing, frequently and for multiple purposes; (ii) a relation between holiday cycling and living in a cycling-friendly country, past cycling experience, and habitual transport mode choice during daily life; (iii) an appeal of electric bicycles to tourists with high interest in bicycle technology, low perceived cycling ease, and weak norms toward cycling; (iv) a relation between frequent and multi-purpose cycling intentions and to stronger attitudes and norms toward cycling, and greater perceived likelihood that the holiday partners would cycle have been highlighted. The possible benefits of bike-sharing include, among others, flexible mobility, emission reductions (thanks to its rapid development, in Shanghai 8,358 t of petrol, 25,240 t of CO_2 and 64 t of NOX emissions have been saved in 2016 according to press release), physical activity benefits, reduced congestion and fuel use, individual financial savings and support for multimodal transport connections. These benefits are nevertheless difficult to measure per se in a complex multimodal transport system. The economic efficiency of public bikes is also being heavily questioned.

Bike sharing sets itself in between sustainability and the process of transformation into smart cities thanks to integrated transport paradigm. Bike-sharing programs have been deemed capable of acting as either substitute for car transport or complement for public mass transport in the access/egress phases and have been pointed at as the champ of sustainable transport commitment by local governments. Additional pros listed enclose being capable of creating new demand, being affordable and supporting social inclusion beyond reducing congestion in major cities. The recent comeback of free-floating schemes allowed additional mobility freedom. Then, why failures not only concerning local managed projects but also the most recognizable brands worldwide? Is it perhaps something within the traditional scheme that has run out of order?

Let in for a moment that bike-sharing could effectively increase cycling levels; on the other hand, complementary pro-cycling measures and open support for sustainable urban mobility are needed in order to reach the goal. Issues such as systematic underuse, vandalism and theft, complicated planning procedures, un-clear expansion scheme, the one-bike-fits-all business model and strict regulation have emerged instead. In addition, from the policy side, the professed political support has in reality demonstrated to be rather mild and had been - broadly speaking - easily thwarted by opposing push and measures reluctant to forsake space to policies supporting cycling, bike stations and the co-existence with car and even pedestrians.

Research highlighted that peer-to-peer sharing is likely to remain a niche, traditional station-based business models are well known but harder to scale up and show flaws regarding the picking/dropping systems and the faltering app connection; finally, the dockless ones have great scaling potential and participation but face the issue of serious oversupply, which is detriment to user satisfaction. This underlines the necessity of additional research on the balance/relationship between fleet size, service and performance. Moreover, literature refers to less than 10% of the launched schemes only, mainly those with positive outcome.

The recent paper by Nikitas (2019) reports quantitative evidence from two survey-based studies and an extensive state-of-the-art analysis of exemplary bike sharing success and failure stories around the world collected from both scientific literature, press releases and reports. As far as surveys are concerned, an existing and hypothetical bike sharing project - respectively in Gothenburg and Drama (Greece) - have been assessed on the fields of acceptability, usage determinants, users' travel habits and attitude towards cycling as well as socio-demographic characteristics.

Bike-sharing projects, adequately designed and promoted, can be acceptable in small and medium sized cities (even those with yet to establish pro-cycling culture) but usage or intended usage rates can be significantly smaller than acceptance due to road safety concerns and lack of adequate cycling infrastructure. Acceptability needs to be sided by strong synergies to allow commercial success and financial sustainability. A lack of long-term vision and ability to create channels with the city hosts and local communities would, on the contrary result, in unrealistic expectations and failure. For example, Gothenburg's dock-based bike sharing has a 90% positive reputation but less than 25% of the interviewed sample include it as a feasible transport option (and less than 3% as the main one). Even non-users are positive towards the scheme and supportive on further expansion and only 6.5% of users express some blames. Main reasons pointed put for not using shared bikes were safety (14.9%) and lacking infrastructure (30.9%), but - above all – the possession of a owned bike (40%). In Drama, where a bike share scheme was not present at the time of analysis, 90% of the respondents declared a positive attitude (bike share could be beneficial, a sustainable option capable of improving traffic condition and complement transport supply, promote wellbeing…), although potential use rates could be biased from excessive optimism (46.9%). Reluctancy has been associated to perceived lack of infrastructure and cognitive gap (50% together), followed by negative perception, need of physical effort and lack of time.

The state-of-the-art review of literature and projects highlighted the following general shortcomings:

- station-based operations do not meet door-to-door requirement convenience. The main flaws in Pronto scheme in Seattle – for example - were poor allocation of stations and the lack of an incremental expansion strategy; wider bus–bike integration would have been needed;
- dock-less and smart stations, with Mobike and Ofo being two of the most renowned examples covering more than 500 cities and more than 20 million bikes worldwide, show a greater capability of scaling operations as Uber had for car sharing programs. Nevertheless, this remarkable growth is accompanied by a fair share of early fiascos and stigmas (e.g. Ofo withdrew from London, Mobike from Manchester and Newcastle; in addition Bluegogo – 3rd biggest Chinese company - went bankrupt in 2017).
- Bleugogo's bankruptcy undermined the statement that a huge number of bikes available at very low prices would be sufficient to guarantee financial sustainability. Unrealistic revenue expectations and the unsustainable pace of the project expansion were the two main causes leading to failure, suggesting that both supply shortage and excess are noxious to the effectiveness of the scheme.

- limited fundraising, lower technology equipment with respect to the average market (i.e. no GPS tracking), theft and vandalism have been a common cause of failure of BSSs over history.
- some operators – such as OBike – withdrew due to overinvestment (i.e. in technology, security, and management) to cope with strict regulation in some countries.
- finally, the cyber-attack that Bycyklen suffered in Copenhagen forced the operator to reboot all 1,850 bikes individually; raising shadows over the security topic.

As a whole, in conclusion, concerns about the long-term viability of bike-sharing and mainstream allegations have been highlighted, overshadowing the very concept of bike-sharing system. Detractors and critic reviewers have labelled ebike as an elite service (due to high costs as a consequence of the stress on the technology side and the central location of the stations) rarely capable of solving transportation and equity issues.

On the other hand, many examples rebate and enforce the positive contributions by BSSs in inspiring modal shift and making bicycle usage more popular. For example, the Hangzhou project started in 2008 with 2,800 bicycles and 60 stations and now includes 100,000 bicycles and 4,100 stations evolving from a complement to existing public transit to a tool for modal shift thanks to high supply, the not-for-profit scheme (i.e. riding is free for the first hour), real-time information system and the existence of a green corridor aimed to promotes cycling. Local projects developed with success alongside private-run ones such as Mobike, Ofo, Hello Bike and Qibei: Barclays/Santander station-based bike-sharing scheme in London has been the largest service of this kind in Europe since 2011. It is accessible by anyone with a credit or debit card and charged £2/day for unlimited journeys of up to 30 min or £90 for the year. A wise expansion scheme - with the strong support by the city council - extended the network to 100 km^2 surface, 11,500 bicycles, 750 docking stations, 240,000 active members (which is nevertheless as less as 3% of London population) and over 10 million annual bicycle hires. The service is well-linked with TFL (Transport for London) network and has enhanced equity and social inclusion in the whole London area. Dublinbikes - launched in 2009 - received strong sponsorships over time by JCDecaux, Coca Cola and Just Eat in exchange for free advertising spaces; therefore, it is one of the cheapest schemes. Another system supported and managed by the city council is present in Barcelona (Bicing – started in 2007) where a dense network of stations is present (more than 400 stations and more than 6,000 bicycles and e-bikes) with low annual fees for residents and commuters. Almost 100,000 subscribers were reached during the first year and the expansion program – originally developed along a 10 years horizon - was accomplished after only 18 months. The technology behind allowed also a vast campaign of residents' mobility behavior survey and the development of strategies to cut carbon dioxide emissions followed accordingly. Bike-sharing integrated into public transport schemes are present in Montreal; the original project filed for bankruptcy and was then revamped by the city council and developed into a non-for-profit integrated service package along with local car-sharing service. The service is particularly attractive for younger people not owing a car and its extension is planned to further reduce social exclusion by means of as much as 60 new docking stations and 1,000 additional bicycles.

Bike-sharing systems have had varying degrees of success; proper strategies need to integrate transport planning, system design and choice of business model. While bike-sharing is a meaningful suggestion for urban policy-makers at all scales (due to large acceptance among citizens and supports expectation from city council), nevertheless usage rate is significantly lower than acceptability. Therefore, usage should not always be considered as the sole success parameter. Standardized business models and operation strategies fail in adapting to local settings and are likely to result unsuccessful. Surprisingly, the majority of successful schemes is based on dock-based systems, despite their inability to provide door-to-door services, even if dock-less ones are useful to complement the service and can survive alongside the former. Expansion has to be planned accordingly with stakeholders and decision makers to suit hosts' needs and avoid pointless investment. A secure support of the local authorities and forged synergies with commercial and technology partners have been the key motivators of success. The crucial role of designers is to define an effective and attractive PSS for bike-sharing. This involves city councils to work collaboratively with different stakeholders, such as institutional investors, advertising agencies, bike manufactures, system operators, and users. Recent studies suggest that for a bike-sharing system to be successful it is essential to be subsidized by local government or other funding bodies whose ultimate goal is to reduce environmental impact, lessen traffic congestion, enhance mobile connectivity, and finally improve public health. The existence of a market for a profit-making business is a necessary precondition for a sustainable bike sharing system. The process of creating a viable business model will take into account design, development, implementation and operations. There are many challenges that face bike-sharing operators: the location and size of bike stations, the forecasting and scheduling of customer demands, route choice and development, bike maintenance and bike-redistribution systems; theft and vandalism; competition from other modal alternatives. The cases show the different elements that make up a configuration of a sustainable bike-sharing system: a proactive and supportive local government that puts in place the right infrastructure, provides high subsidy and enforces their correct use, as well as the participation of agencies to ensure the smooth operation of the system. A sharp focus on the product needs high initial capital investment in equipment but the investment in quality repays itself in the long run. A sharp focus on the service requires a clear understanding of what value is attached to bike-sharing systems by users and designing a system accordingly. The overall conclusion is that any configuration has to consider all these disparate elements together.

Some key recommendations can be hence summarized:

- the "one business model fits all" approach is not working;
- prioritize the long-term success over easy and fast profit and unrealistic revenue return expectations. Bike-sharing services should be user-centric and not profit-centric to be successful;

- operators should actively seek the support of the cities (i.e. subsidies and supporting infrastructure) in parallel with subscriptions and rentals profits;
- seek strategic commercial collaborations, such as public-private partnerships and branding, to help in sustaining business;
- travel supply should mirror travel demand; when competing providers exist, the new player needs to offer a "twist" to what is already available;
- develop responsible usage practices in close cooperation with city councils;
- promote and raise cultural engagement;
- focus on fair subscription and fee policy;
- pursue innovation to stay on top of the market;
- technology is only one of the tools in the toolbox; however, mobile apps, rental machines, GPS tracking and locking systems are of vital importance and should be modern and user-friendly;
- infrastructure should be attractive and well designed and prevent anti-social behaviour;
- diversify the fleet to address female or weak users' needs;
- in touristic cites, the needs of tourists should be embedded in the planning of bicycle lanes and facilities, i.e. by combining short routes with circular routes that allow scenic and historical areas to be reached;
- surveying the use patterns by demand group (e.g. tourists, commuters, residents, occasional users) could be beneficial to transport planners;
- bicycle technology motivates the choice of electric bike but the demand for electric bikes is much lower than for manual ones, which is important from the financial side of the service; therefore new bike-sharing system should not be focused on electric bikes straightforwardly, but on manual bikes that can be easily upgraded to electric;
- people who reside in non cycling-friendly countries/cities exhibit higher enthusiasm towards using the bike-sharing system, while people residing in cycling-friendly countries/cities exhibit the opposite trend maybe because they already perceive it as a part of their habit. Therefore, also marketing strategies shall be different: cycling-friendly users would require mainly information on the city sightseeing, while other users might be captured by advertising tourist-related experience such as guided city tours by bicycle and one day cycling courses to increase the attractiveness;

- cooperation to enhance safety and adequate infrastructure provision.

Policy-makers and scheme suppliers shall be aware that citizens perceive positively systems that deliver sustainability benefits being supported by the local authorities. This result, combined with field evidence that bike-sharing schemes could be underused and thus may not be commercially profitable when income depends solely on subscription and short rental rates, signifies the need for establishing strong links and commercial partnerships with the city hosts and private industries interested to associate their brand with bike-sharing. In addition, a design tailored to hosts' requirements, clear and realistic expansion strategy, commercial – operational - regulation synergies, engagement, fairness and easiness to use are key aspects to be included in the project from the earliest phases.

14.PRELIMINARY FEASIBILITY ASSESSMENT OF THE CASE STUDY

As it has been mentioned in the section above, the financial aspects connected with services of this kind are of paramount importance. A lot of projects examined have been funded and started under the terms of public grants, EU research projects, crowdfunding or with the strong support of the city councils which have no doubt been helpful in ensuring at least the partial coverage of infrastructure and fleet costs. Therefore, all the recommendations above derived from the literature, press and project report have to be kept in mind, especially those concerning the financial implications and the economic sustainability and feasibility 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.

	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	Staff	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	

Table 4. Cost and profit items of the MOSES project

2.1 Fleet, spare parts, maintenance contracts

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 (e-bikes for private users are assumed to be charged every day) and to replace exhausted batteries every 2 years.

Even if within the MOSES project bikes have been developed by a project partner, it is still worth mentioning some key monetary aspects related herein. In particular, it is significant pointing out that each new market player willing to enter/start a market must not adopt bicycle whose features (i.e. design, technology …) are below the average threshold of the market, as users familiar with bike sharing programs will immediately notice the difference and disregard the service. Technology progress are so fast that models go quickly out of the business; in addition, also the sampling of additional spare parts can become difficult as time passes by. To sum up, fleet has to be top-notch as far as technology and easiness of use are concerned. Therefore, the average lifetime of each vehicle equal to 2 years is both related to its wear-and-tear but also to the necessity to stay at the pace of the market. Fleet's lifetime is directly dependent to quality and with quality comes cost. Therefore, average quality and medium-high design are needed for the project to be attractive to users, but costs incurred have to be repaid over time mainly by means of the tariff scheme and the rental of additional items (i.e. locker, helmet …) issued to users. Other forms of funding such as merchandising, crowdfunding and subsidies are to be sought and raised to guarantee the viability of the project.

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. For private use high-end models are preferred, while for bike sharing purposes medium-low price models can be acceptable without losing the focus on quality. While some parts are totally similar to those of traditional bikes (tires, headlights, brake pads), additional cost for e-bikes is mainly due to the motor, battery, design and electrical equipment. The main issue of e-bikes is in general the increased weight with respect to traditional models; nevertheless, high-level items are made of carbon fiber and allow less than 15kg unladen weight. E-bike provides greater ease or efficiency in climbing hills or against the wind compared to traditional bike.

In particular, 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 on average between 25 and 100 km. The factors that usually affect the range are the user's weight, the cruise speed, battery age and the morphology of terrain. High-level e-bike manufacturer usually provide high-density cell batteries to extend the range and high ampere charger so that to shorten the idle time of the battery to as much as two hours. In addition, batteries can be removed and charged off-line inside a battery bank and this is extremely positive for bike sharing purposes. Depending on the use purpose, private users would better seek long lasting longevity: 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 respectively, depending on the usage and the quality. The cost of the battery is paid off along the lifespan of the battery; given that the first battery is sold together with the e-bike, the annual cost of the battery becomes apparent once the original one is exhaust. For the purpose of the MOSES project then, battery costs would less impacting on the balance sheet (given the fact that the whole fleet is planned to be renewed every two years); nevertheless 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. Battery packs can be made up of many cells and sometimes these cells become unbalanced. Many modern batteries keep themselves balanced correctly. However, it is possible to charge the individual cells to balance them all. To enlarge the average duration of the whole pack, store the e-bike and the battery out of direct sunlight when they are not being used. If it's off the bike, keep the battery in a cool dry place, ideally below 20°C. If the battery is stored for a lengthy period, it is better ensuring a partial charge between 40%-80%. Finally, don't keep it on charge for a long time, because it reduces the battery life (although modern lithium-ion batteries are less sensitive to this issue).

The motor can offer several levels of support (which have different consumption rates of course); moreover, a LCD display from which performance statistics, maps and GPS tracking and premium smart options (possibility to text messages or issuing alerts in case of accident or theft) can be present. It is advisable keeping the chain lubed and protected from mud (a fender and a mud-flap would help) to guarantee shifting performance, bike reliability and chain/sprocket life for a long time. Usually the chain needs to be substituted every 1,500 km – 2,000 km depending on the use.

As previously said, 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. Basic daily maintenance plus periodic maintenance are capable of extending the e-bike lifespan. The annual cost of basic maintenance and spare parts ranges between 100€ – 200€ (tires, brake, drivetrain fix, bike tune up, manpower). The electrical part generally will require little maintenance (display screen, cabling, electric motor; in case of issues, most probably they need replacing rather than maintenance). General cycle tips to enlarge the lifespan include cleaning, avoid jet water for washing purposes, keep the chain lubricated and the tires inflated. Kevlar-lined tires cost more but the durability and performance are greatly improved. Finally, spokes are the most fragile parts due to the higher speed and hence they need replacing every 500 km (thicker ones are better than thin ones), while brakes need changed every 1,500 – 2,000 km.

The charging costs are negligible if a single battery is taken into consideration. To make an example, a 400Wh battery (0,4kWh, which is the battery voltage per the amp hour rating) multiplied by the average price of energy (0,06€/kWh in Italy, which is the rough average between day and night/weekend tariffs), by the average time required to reach a complete charge and by 365 to obtain **the annual cost**, makes up less than **30€/year/battery** (a single charge is worth less than 0,10€).

To conclude, given the high value of the package, safety and security items must be of very high quality: therefore, a secure lock can be worth as much as 100€, while lights and bell are worth additional 50€. For example, the smart lock provided by *bisecu* (https://www.bisecu.com/) pounds less than 400g and serves both as a locker when the bike is idle and as a performance tracker when the cycle is active. It is connected to the front wheel and can be integrated with the cable stuff of the standard e-bike (probably at the detriment of the range). As a locker, it blocks the hub of the wheel when activated via Bluetooth within a certain distance from a mobile app (thus, it is key-less) and produces a noise worth 100 dB if bike tampering occurs. Standard USB charge. As a performance tracker, it keeps memory of distance, actual and average speed, time and calories burnt.

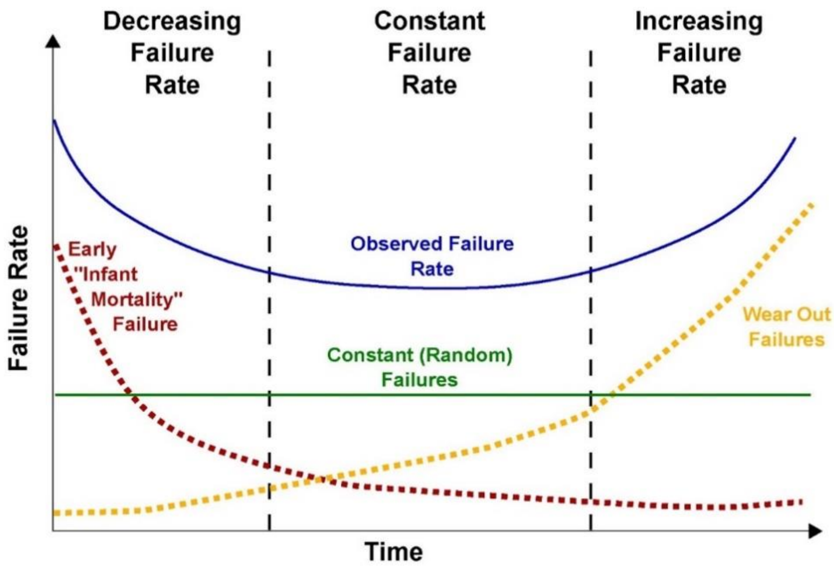

Figure 24. Failure rate of Electric bikes over time

The graph in the figure above shows that the most failures happen at the very start just after purchase due to electrical failures (when warranty is applicable) and at the end of lifespan due to wear-and-tear (when buying a new bike is better than fixing the old one), while during most of the lifetime only random events occur.

As it is summarized in the table below, which doesn't include initial purchase price and parking price for the car, e-bikes cost more than a traditional bike but even though significantly less than a car when all running costs (internal and external) are concerned.

Cost item (avg €/year)	**Bike**	**eBike**	**Car**
Insurance	-	-	1,000€ on avg
Fuel / charge	-	30 €	1,000 – 2,000 €
Servicing	100 €	200 €	300€+
Components	100 €	150 €	700€+
Battery	-	- (until the 1st battery is exhaust)	25€
Average Annual cost	**200 €/year**	**Around 400 €/year**	**3,500 €/year**

Table 5. Comparison of maintenance cost items

Purchase cost on odd years = 30 x (1,500 + 400) + 20 x 200 = 60,000 €/year
Purchase cost on even years = 400 x 30 = 12,000 €/year
(NB: 30 bikes and 20 additional batteries, in addition to the 30 in stock)

2.2 Personnel and public land permission

Bike sharing – both docking and free float – are generally designed with bicycles made available via online reservation or via mobile app. Therefore, expenses for personnel are reduced. 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.

Normally, personnel are needed at the help desk and for bike rebalancing if planned during nights. As long as a likely extension of the program is planned, additional personnel units are usually hired. Quickbyke project has made of personal touch a key of success, with personnel units helping for instruction, merchandising and for organized and guided city tours. Therefore, this is a cost item that needs careful design. If a service similar to the one offered by Quickbyke is assumed, at least 3 personnel units are needed to cover shifts and rota during the week and this is worth as much as 6,000 €/month gross wage.

Public land use permission for the installation of the MOSES hub depends on the location chosen. A feasible strategy for the service operator would be looking for local authorities' commitment and sponsorship in order to cut this cost item. In addition, many examples have demonstrated that sharing responsibilities and objectives with the local level beforehand facilitates a positive outcome and is good also from the financial point of view.

As far as expenses concerning energy supply are involved, the theme is whether trying to pursue self-supply by solar panels or linking to the network. In this last case (the former option will be discussed later on), given the measures of a standard 40ft container, as much as 1,000 €/year for electric supply are assumed (which takes into consideration heating/cooling, lighting and power supply during night to charge dead batteries)

Personnel and public land permission + energy supply = 6,000 x 12 + 1,000 = 73,0000 €/year

2.3 Re-engineering

Unladen weight		3,630 - 3,740 kg	
Maximum load		26,740 – 26,850 kg	
	External	Internal	Door

Lenght	12,192 mm	12,010 mm	–
Width	2,438 mm	2,300 mm	2,290 mm
Height	2,591 mm	2,360 mm	2,260 mm
VOLUME	65,20 / 67,7 m^3		

Table 6. Features of a standard 40ft container

The table above contains the average measure of a standard 40ft container, which is the type chosen for the MOSES pilot project. Similar solutions have been adopted by Quickbyke (see below, photo courtesy of the owner available at https://flickr.com/photos/quikbyke) and is proposed also by Cyclehoop – which is a designer of cycle-parking and infrastructures. The re-engineering of the 40ft container with front opening instead of the traditional side opening is a costly option in Italy, since no vendor of such services exist.

Figure 25. The Quickbyke pilot project (courtesy of the owner)

Cyclehoop Container Cycle Hub is a 20ft container (length 6,100 mm x Height 2,957 mm x Depth 2,440 mm, with Internal Height of 2,690 mm and useable internal height for cycle racks of 2,645 mm) rearranged for the purpose of becoming a functional and secure cycle mobile hub. The container has a double full height sliding gate made of perforated steel on the front side. The Container Cycle Hub offers a secure solution to cycle storage and can be easily transported to most locations. It can be installed in less than a day and thanks to its modular design; multiple units can be added side by side, thus expanding cycle parking capacity. Internally, two tier racks double the amount of cycle parking supply. It also includes motion sensor lights, solar panels, a pump and repair stand. Main features which have been quoted from the website (www.cyclehoop.com) are:

- parking for 24 bikes

- Requires minimal planning permission
- High security sliding gates with a mechanical slam lock
- Gates made from perforated steel panels to allow natural light into the unit
- Mechanical code lock with an anti-code detection
- Fitted with Dutch V10 Two Tier Racks with a welded locking bar
- Dusk to dawn motion sensor internal lighting
- 250w Solar Panel (German Polycrystalline) and battery
- Wall mounted public tool box
- Compact Pump

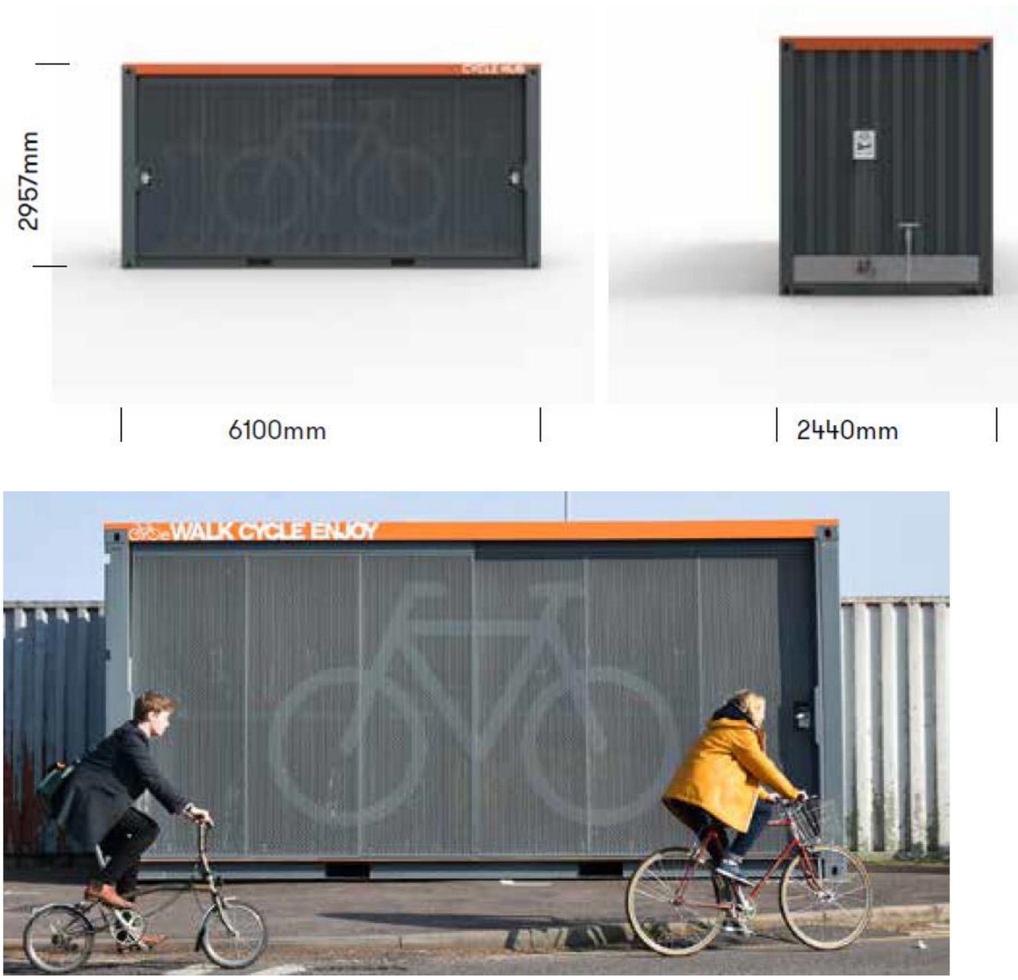

Figure 26. Cyclehoop's container "Cycle hub" (website)

Additional items invented by the same firm and available on-sale even via online channel are Vertical bike rack, horizontal and semi-vertical bike shelf and the Dutch Two Tier Rack – Optima V10 which is included in the container hub to double the room for storing cycles. Quoted specification of each one is included in the followings.

2.3.1 VERTICAL BIKE RACK

The Vertical Bike Rack (registered EU product) enables bikes to be vertically mounted to any surface to save storage space. The item is made from 8mm steel rod. Measures are 340 mm Height, 91 mm Width, 580 mm depth). If bikes are mis-aligned the lateral distance can be reduced to 35 cm, otherwise 70 cm are needed to accommodate bikes (thus halving storage capacity). **The cost of each item is 24,95 GBP = 28,11 € (VAT excluded).**

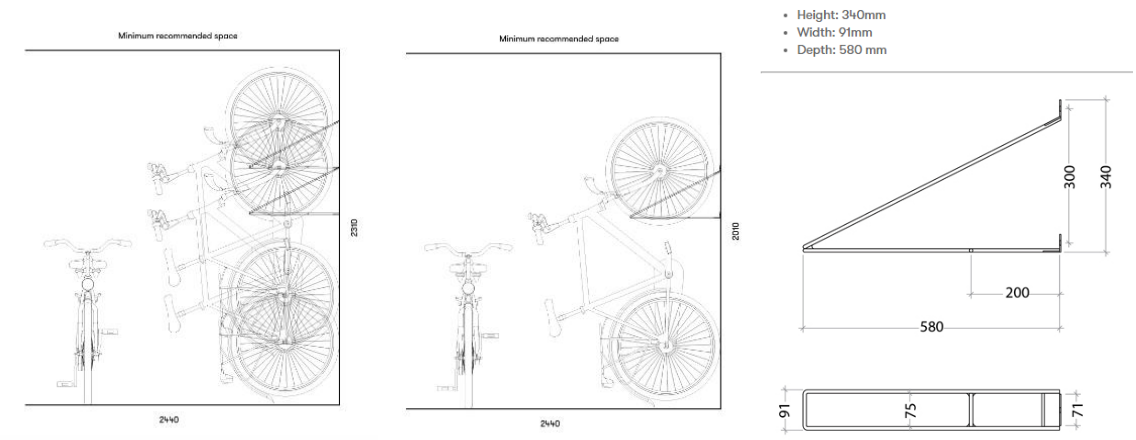

Figure 27. Cyclehoop's vertical bike rack specifications

2.3.2 HORIZONTAL BIKE SHELF

The Bike shelf is 5 mm thick sheet of steel mounted onto a wall to hold the bike, bag, helmet and lock etc. Due to its design, the storage capacity on a wall is reduced. Available in five different colours (White, Dark Grey, Orange, Green and Turquoise), the Bike shelf features a protective rubber element to prevent scratches on your bike. Weight: 9 kilos (must be installed on a load bearing brick or blockwork wall) so that it can hold bikes with a top tube diameter of 50mm or less. Dimensions: 180 mm height, 300 mm width, 330 mm depth. **It costs 66.50 GBP = 75 € excluded VAT.**

Figure 28. Cyclehoop's horizontal bike shelf (website)

2.3.3 SEMI-VERTICAL BIKE SHELF

The Semi Vertical Bike Shelter provides efficient parking for your cycle. It is manufactured from rolled solid steel and is available in a range of colours and finished with a galvanized or powder coating. Optional locking bar and side panels allows cyclists to lock both wheels and frame. Dimensions: 1,830 mm height, 1,150 mm depth, 350 mm rack spacing. It is scalable to any width dimension, and obviously the price depends on this figure.

Figure 29. Cyclehoop's semi-vertical bike shelf

2.3.4 DUTCH TWO TIER RACK – OPTIMA V10

The Dutch Two Tier Rack – Optima V10 is a space saving solution that doubles the amount of cycle parking compared with traditional cycle racks. Its space saving, robust design doubles the amount of cycle parking compared with traditional cycle rack, making it ideal for high density areas such as major transport hubs, offices and shopping centres. A gas assisted lifting mechanism allows easier use of upper sections. Bicycles can also be chained for security. It can be extended infinitely in width. Minimum required headroom: 2,750 mm; recommended minimum aisle space 2,400 mm and centre to centre size of 400 mm. **The cost is 159 GBP = 180 € per space, VAT excluded.**

Figure 30. Cyclehoop's Two tier rack (website)

How many bicycles can each of those solution accommodate in a mobile hub container such as the one used in MOSES project which is 12,000 mm long?

- Vertical bike shelf aligned solution = 12,000 / 700 = 17 bikes. The amount of space occupied in depth is roughly 1,000 mm → **total cost of the solution around 600,00€ VAT included for 17 bikes**.
- Vertical bike shelf mis-aligned solution = 12,000 / 350 = 34 bikes → **total cost of the solution around 1,100 € VAT included for 30 bikes**
- Horizontal bike shelf: here the leading measure is the length of a standard bike which is almost 2,000 mm; we can assume a mis-aligned solution and we obtain as much as 11 bikes → **total cost of the solution around 1,100 € VAT included for 11 bikes**
- Semi-vertical bike shelf: as the spacing is similar to vertical mis-aligned solution, the number of bicycles storable is the same. In addition, since the container is 2,400 mm deep, this solution occupies almost half of the container's depth → no information on the price has been found on the website, but **a price of 2,000 € VAT included for 30 bikes** can be assumed
- Two-tier rack: the dimension of the container is sufficient to accommodate the two-tier rack since it requires 2,400 mm depth which is slightly less than MOSES hub's depth (2,440 mm). Therefore,

up to 60 bikes can be stored within a 40ft container. Otherwise, 30 bikes can be accommodated on one half of the container and rest of it arranged with desk and merchandising items as well as for light maintenance and for eventually storing additional items such as safety equipment and foldable/mobile solar plants and battery bank → **total cost of the solution around 3,500 € VAT included for 30 bikes**

Two-tier rack is a useful solution also for MOSES projects as it permits all the furniture needed to run the depot autonomously. Batteries need to be charged offline to make operations easier. The only issue, beside the relevant cost, is the fact that e-bike's weight is not negligible, and this would be a serious drawback for the operator (but also for the potential user) were the gas assisted lifting mechanism not available.

2.4 Full-solar panel supply

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.

Speaking of how little it costs to charge an electric bike, what about charging it via solar power? E-bikes use so little energy compared to electric cars that it really is possible to get around via a solar powered vehicle, today. Solar panel usually lose part of their performance over time, but the loss amounts to as much as 10% in a time span of 25 years. Due to the necessity of switching to green supplied electric energy, a larger use of storage systems for electricity generated by solar power systems will be needed. It is necessary, then, that the storage system features a multi-inverter that achieves a high charging efficiency allowing users to optimize energy use.

The New Wheel – an e-bike specialist retailer and service supplier based in the san Francisco area – installed a SolarPump station produced by Sol to charge its fleet of pedal-assist electric bikes and offer free solar-powered outlets for customers to charge their e-bikes and mobile electronics. The charger has three solar panels and is capable of charging 10 e-bikes at once, said Brett Thurber, who co-owns The New Wheel with wife Karen. Time for a full charge runs about two hours, depending on the speed of the bike's own charger and its battery capacity.

Can e-bike batteries be charged with solar panels? Yes, but it is a complex question. Most solar panels put out under 20 V on a very bright sunny day and they are designed to charge 12 V batteries. Therefore, the voltage of your panels needs to be boosted to be capable to charge a 36 V e-bike battery. These MPPT exist, but they are relatively expensive (around 300 €). A full charge would need large panels and very bright sun for a long bunch of time (e.g. 2 panels x 100 Watts, 1,2 x 1,2 m, 250 €/each; portable and folding panel exist as well but are much less efficient and more expensive). Theoretically, a good quality 12 V, 20 W, mono-crystalline solar panel will produce approximately 14 V at 1.3 Ah (under load), so if you series-wire up 4 x 20 W panels, you'll have approximately 55 V at 1.3 Ah (roughly the same that a standard 48 V e-bike charger produces) and they would need almost 2 days to charge a deeply discharged ebike battery, assuming good weather and no shade. In addition, this structure needs to be portable!! Therefore, we can conclude that direct solar charge of batteries is theoretically possible but rather difficult practically. Home solar plants work because a roof can host a lot of panels harvesting energy all day, as long as the roof isn't shaded. Foldable solar panel chargers are useful for people going on camping and needing additional power supply if they run of battery of their PC, phone, power stations etc. and therefore they are worth in between 20 - 100W and they cost 100 – 200 € each! This supply is largely insufficient to charge a battery of e-bike! We need to bear in mind that e-bikes need a powerful motor and therefore a powerful battery to carry on people worth 80kg for 50km range on average! In addition, bikes are supposed to be rented during the day and available again at evening-night; therefore, solar energy need to be stored during the day and used to charge the batteries during the night. This is the only option, although, from an energy point of view this is not efficient since two conversion between direct and alternate current are needed. 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.

The specification sheet of the e-bikes states that batteries need 5 hours to be 100% charged. Depending on the battery size and type, the actual charge time ranges between 2 - 6 hours on average. 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. Therefore, our plant - to guarantee 10,8 kW - would cost around 9,200€. In addition, we need the storage system, which will make our bill bigger. We found on the market two feasible solar generator supplier capable of supplying the power needed.

2.4.1 IKUBE F150

It is a ready-to-use mobile solar generator with 2 inverter power options: 3.2 kW and 4.0 kW. It is designed to provide electricity in all areas of the globe not covered by a distribution grid and for all uses that require to be able to move their energy source, Ikune can work even in the absence of sunshine offering the advantage of compactness, low noise, no fumes and fuel costs. The batteries contained in the base of only 1 m^3 are recharged by the photovoltaic generator which, with its surface of 9 m^2, develops a power of 1,4 kW.

iKUBE F150

Inverter Power	4.000 VA / 3.200 W
Dimensions	1,27x1,27x1,20 m
Weight	550 Kg
Autonomy (1 KW load)	10 h
Battery Pack	48V 225 Ah
Generator Power	1,4 KWp
Photovoltaic surface	9 m²

Figure 31. Ikure F150 (website)

Power 1400 Wp, Inverter power 3200 W, Batteries (N - V - AH) 8 - 6 – 225, battery bank capacity 10800 Wh, dimensions (closed) 127x127x120 cm, (open) 256 x 313 x 227, weight 550 kg. F150 model is available, upon request, with the following features: double battery bank (21,6 kWh in total), 4 kW inverter, parallel operation up to 4 units (or 10 units) for a modular mobile solar farm, DC output12V / 24V / 48V, AC output 110V / 60Hz, 3phase output with 3 units, remote monitoring just with 3 KW inverter, trailer. Technical sheet available at:

http://www.ikube.it/dev/files_datasheet/1_0_file1_160901_iKube_F150_Technical_Sheet.pdf

Base price = 7,000 € - 8,000 € VAT included + solar charge bonus.

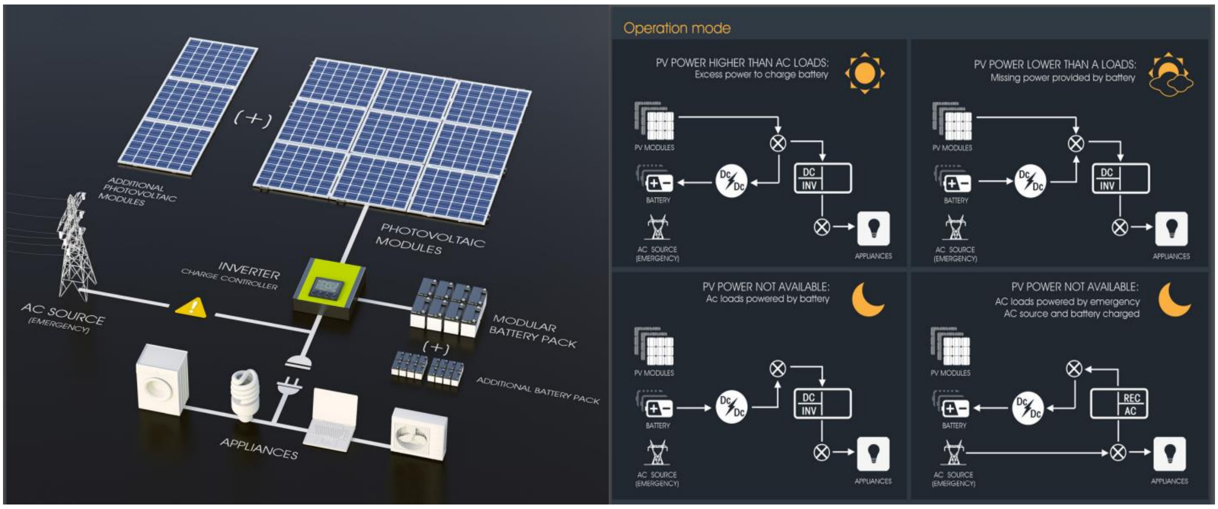

Figure 32. Scheme of operation of solar module (right: top-left and bottom-right mode) (website)

Basically, depending on the power required, the duration of the Ikube F150 varies:

Power [W]	Duration [h]
100	165
500	22.5
800	12.6
1000	9.5
1500	5.8
2000	4.0
3000	2.4

Table 7. Relationship power - duration for Ikure F150 (website)

Also, the production available [kWh/day] varies depending on the location and the period of the year, with a peak in summer 7,5 kWh/day and a low in January 2,65 kWh/day. The yearly average is 5,11 kWh/day.

2.4.2 MOBILE SOLAR

This is a compact mobile solar generator designed for events, job sites and small remote homes; guarantees a balance between power (3,5 kW) and transportability, it can be towed by road vehicles and is useful for residential back up, disaster relief and small construction sites. Solar Trailers are built with high-efficiency solar modules and industrial battery banks. No noise. No fuel. Very little maintenance. MS-150 has 3 panels x 335-watt LG monocrystalline modules (6kWh/day), 120Vac Output, 3.5kW rated, 15kWh battery capacity.

4' x 6' enclosed trailer by LGS Industries, Rated GVWR: 1,750 kg, Rear Door, Smart Battery Meter, Industrial Steel-Case Lead Acid Battery, Automatic Watering and Degassing System, Average Battery Life: 12-15 years, Generator/Grid input, **Price: 16,000 - 20,000 € VAT included + solar charge bonus.**

Figure 33. MOBILE solar LGS MS150 (website)

Technical sheet available at:
https://www.mobilesolarpower.net/wp-content/uploads/2018/10/MS150_Spec-compressed.pdf

Since W = V x A and e-bike batteries are worth 36V x 10A x 5 hours for a full charge at the maximum power, only 3500 W / 360 W/bike = 9 bikes can be charged at the same time → therefore 3 items are needed to charge 30 batteries at the same time. This will make price skyrocket.

The fact is that solar panels store energy in direct current inside the battery pack. The batter pack is linked to an inverter that performs the transformation direct → alternate current, thus allowing energy supply in a way similar to domestic situation. E-bike charger is equipped with a transformer that performs the inverse transformation 220 alternate current → 36V direct current so that e-bikes' batteries can be charged during night. Despite that, the double transformation is not efficient from the energetic point of view since energy loss are evident. The main point is how many batteries need to be charged at the same time and which is their initial status. In addition, if we keep voltage constant but reduce amperage, we would be able to charge twice the number of batteries at the cost of an enlarged duration of the process. Since charging operations take place during night, this is a non-problem! This way, with a 36V 5A 10 hours, 18 batteries can be charged at the same time and hence only 2 items are actually needed. A transformer alternate – direct 220 V A 36 V 5 A is needed for the batteries and each item costs less than 10€, which is way cheaper than an additional solar energy storage unit.

	MS-models	MS-150	MS-200	MS-225	MS-275	MS-325	MS-375
Inverter	Rated Output	3.5kW	3.6kW	7.2kW	7.2kW	7.2kW	7.2kW
	Surge Output	6kW	6kW	12kW	12kW	12kW	12kW
	Output Voltage	120VAC/60Hz Or 230VAC/50Hz	120VAC/60Hz Or 230VAC/50Hz	120/**240**VAC/60Hz Or 230 VAC/50Hz	120/**240**VAC/60Hz Or 230 VAC/50Hz	120/**240**VAC/60Hz Or 230 VAC/50Hz	120/**240**VAC/60Hz Or 230 VAC/50Hz
	Phase	1-ph	1-ph	1-ph	1-ph (3-ph opt.)	1-ph (3-ph opt.)	1-ph (3-ph opt.)
	Rated Amps (Max)	30 Amp 120V (70 Amp)	30 Amp 120V (70 Amp)	30 Amp 240V (70 Amp)	30 Amp 240V (70 Amp)	30 Amp 240V (70 Amp)	30 Amp 240V (70 Amp)
	Manufacturer	Outback Power	Outback Power	Outback Power	Outback Power	Outback Power	Outback Power
	Waranty	5 year	5 year	5 year	5 year	5 year	5 year
Battery	Capacity	15 kWh	20 kWh	25 kWh	30 kWh	35 kWh	40 kWh
	Amp-hours	627AH @ 24VDC	418 @ 48VDC	523AH @ 48VDC	627AH @ 48VDC	732AH @ 48VDC	836AH @ 48 VDC
	Type	Industrial Lead Acid	Industrial Lead Acid	Industrial Lead Acid	Industrial Lead Acid	Industrial Lead Acid	Industrial Lead Acid
	Manufacturer	IBE	IBE	IBE	IBE	IBE	IBE
	Warranty	7 year	7 year	7 year	7 year	7 year	7 year
Solar	Daily Harvest	6 kWh	12 kWh	12 kWh	18 kWh	24 kWh	32 kWh
	No. of Panels	3	6	6	9	12	16
	Module Watts	335 watts	335 watts	335 watts	335 watts	335 watts	335 watts
	Total Array Watts	1,005 watts	2,010 watts	2,010 watts	3,015 watts	4,020 watts	5,360 watts
	Manufacturer	LG	LG	LG	LG	LG	LG
	Warranty	25 year Ltd.	25 year Ltd.	25 year Ltd.	25 year Ltd.	25 year Ltd.	25 year Ltd.
Charge Controller	Max Amps DC	60A	60A	60A	80A	80A	2 x 60A
	MPPT	Yes	Yes	Yes	Yes	Yes	Yes
	Display	MATE2 (MATE3 opt)	MATE2 (MATE3 opt)	MATE2 (MATE3 opt)	MATE2 (MATE3 opt)	MATE2 (MATE3 opt)	MATE2 (MATE3 opt)
	Manufacturer	Outback Power	Outback Power	Outback Power	Outback Power	Outback Power	Outback Power
	Warranty	5 year	5 year	5 year	5 year	5 year	5 year
Trailer Platform	Inner Dimensions	4′ x 6′	5′ x 9′	5′ x 9′	5′ x 16′	5′ x 16′	6′ x 20′
	Shipping Dimensions (L x W x H)	8′ x 5′-6″ x 6′-3″	12′-7″ x 7′ x 8′	12′-7″ x 7′ x 8′	20′10″ x 7′ x 9′-3″	20′10″ x 7′ x 9′-3″	24′ x 8′ x 9′-3″
	Est. Total Weight	1,800 lbs	2,400 lbs	3,200 lbs	5,000 lbs	5,650 lbs	6,500 lbs
	Total GVWR	3,500 lbs	3,850 lbs	3,850 lbs	7,770 lbs	7,770 lbs	10,000 lb
	Manufacturer	LGS Industries	LGS Industries	LGS Industries	LGS Industries	LGS Industries	LGS Industries
	Warranty	6 year	6 year	6 year	6 year	6 year	6 year

Figure 34. Mobile solar LGS equipment – technical sheet (website)

Leaos created an electric bike that integrates solar technology into the bike's body so that its battery is almost always getting a charge. The solar panels are on both sides of the bike, so that it can capture solar energy even in motion. The objective is not to charge an empty battery from the sun, but to use solar energy so that the battery never gets empty. This gives it a range of about 62 miles in pedal assist mode, of which as much as 10 miles enabled by the solar panels' contribution only, which is the medium usage of a bike per day. Instead of trying to hide the solar panels, a lot of attention was given to incorporating them into the bike. But all of this technology impacts on cost: indeed, the Leaos Solar bike's base price is about 9,000€.

2.5 Advertisement campaign and insurance

It is not possible to provide information on this item cost. Broadly speaking must-have factors to be included within the cost assessment can be brand registering, web domain, buyout and creation of brand merchandising (for example, a T-shirt with a stamp of the brand on is worth around 10€ for the producer and the unit cost decreases with the amount of items); the same holds for safety item that can be purchased and "brandized" from the manufacturer. For this reason, commercial agreement and strong commitment between the producer and the operator is advisable to cut this cost item.

The cost of insurance depends on the size of the project and it includes vehicles, container, personnel as well as users against accidents, injures and damages caused by/to the e-bikes. Part of those cost can be transferred to the user by means of a sound price scheme.

In addition, part of those costs is recurrent (e.g. insurance has to be paid every year) while other don't (e.g. brand registering and expenses for merchandising vary over time, with a higher expense at the beginning and reduced costs in the future).

2.6 Displacement

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 financially. With particular reference to side loaders, which appear to be a feasible solution to handle the box, they are made of a couple of hydraulic and articulated cranes arms to lift the box by means of joint and chains and move it from the ground to the trailer, between trailers or between trailers and rail carriages, and backwards. Stability is ensured by hydraulic stabilizers on the ground. An operation requires less than 5 minutes and only one unit of personnel which can be the driver himself. It is also possible vertically piling two boxes with the same device.

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 side loader. 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.

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. Table below summarizes the cost for displacement with some examples on varying the distance.

The travel cost is the cost of displacement between nodes A and B. The additional travel cost is the cost of displacement of the side loader and truck to get to node A from the closest base and to travel back from the container destination (node B) to the original base. The travel company has two vehicles, based in Trento and Genova respectively. The additional travel cost will depend, thus, from the daily schedule of the vehicles and from the itinerary linking the nodes A-B and the closest base of the travel company.

Origin = port of Ravenna
180 km distance travelled = port of Ancona
320 km distance travelled = port of Pescara
500 km distance travelled = port of Formia

Distance travelled [km]	**Cost for the Lift operations [€]**	**Travel cost [€]**	**Additional travel cost [€]**	**Total cost [€]**
180	140	261	730 x 1,45 = 1,058,50	**1,459.50 €**
320	140	464	880 x 1,45 = 1,276	**1,880.00 €**
500	140	725	1,000 x 1,45 = 1,450	**2,315.00 €**

Table 8. Displacement costs

2.7 Re-charge technology

A capable battery box for charging multiple batteries at the same time has to be provided and installed within the mobile hub container. Otherwise, a prototype modified kickstand to allow wireless recharge has been conceived and tested at the campus of TU Delft university. According to the brochure, the modified double legged kickstand uses the magnetic field generated by the tile to charge the battery. It is fully automatic and can be added to every e-bike to enable it to use the wireless charging system. The producer is currently looking for pilot customers in a market setting.

The brochure is available at: https://img1.wsimg.com/blobby/go/094650d2-a0c5-4dda-8f21-f1930e90509b/downloads/Info%20brochure.pdf?ver=1559822203564

15.OBSERVATION ON THE PRICE SCHEME

To summarize, we need to find out the yearly output of the MOSES project. We have assessed as much as 10 cost items (the cost of the wireless recharge technology is discarded, since it is still a pilot project looking for a market application). Some of those cost items are already a €/year evaluation, while other are single event; for costs related to a single event (namely the re-engineering of the container and the solar equipment) a 10-year lifetime is assumed to obtain €/year cost items.

Cost item	**Quantity - €**	**€/year**
Fleet	1,500.00 x 30	
Maintenance	150.00 x 30	
Charge with network electric supply	30 x 30	
Light/bell	50 x 30	
Locker	120 x 30	
Additional batteries	200 x 20	
Total cost odd years	59,500.00	59,500.00
Total cost even years (only maintenance - charge)	5,400.00	5,400.00
Average yearly cost		33,000.00
Personnel (nr. 3 units) + local taxes	36 x 2,000.00 + 1,000.00	73,000.00
Re-engineering (single event cost item)	15,000.00	1,500.00
Solar equipment (single event cost item)	16,000.00	1,600.00
Advertising		3,000.00
Displacement		5,600.00
Total round off cost per year		**120,000.00**

Table 9. Total round off cost per year

Advertising cost has been assumed for brochure – T-shirts – brandished items, website and mobile app; displacement cost has been derived assuming a round trip between the 4 locations targeted. Personnel cost can be cut-off by hiring part-time worker and winding-up the option of guided tours; in this phase 3 full-time units of personnel have been assumed to run the depot/merchandising and a guided tour at the same time, while being compliant to work shifts and rota. Under those hypotheses, it is adamant that the profit items (Rental activities – dependent on the tariff scheme, Bike tour, Merchandising, Crowdfunding and grants, Online purchase made by users and profits related to advertising) have to be carefully assessed in order to reach a break-even.

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. 20 bikes out of 30, actually used for 300 out of 365 days/year, for 7 out of 10 hours/day at 3€/hour would return 126,000.00 €. The project would be viable even without merchandising and guided tours.

16.CONCLUSIONS

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

- Balance the strength points of established a cycle-based public transport systems;
- Address the seasonality issue connected to touristic flows and sustainable transport solutions offer;
- 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 this work demonstrates that as 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 solutions in providing and promoting 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 centre had a fundamental role. In fact, as evidenced by the qualitative data collected from with the survey, the users declared they would have never been able to reach the city centre were these cycle paths not 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” solutions tested in Ravenna during the Moses project demonstrated as there are 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 compared to traditional bike sharing station based services.

Among the general tips contained in the introduction section of this report, a particular focus is needed – as iteratively rebated – on the following aspects:

- Actively seek the support and periodic feedback from the cities (i.e. subsidies and even more important supporting infrastructure which is critic to get sufficient demand) as well as strategic cooperation opportunities at the local level - such as public-private partnerships and branding - to help the business;
- Supply should mirror travel demand; quality of the service has to be pursued both from the vehicle/technology and the service/personnel sides. For this reason, a periodic turnaround of fleet and furniture is necessary;
- Fair subscription and fee policies;
- Marketing and advertising strategies need to integrate with the service provided (e.g. mobile apps, rental machines, GPS tracking and locking systems) and should be modern and user-friendly;
- In touristic cites, the needs of tourists should be embedded in the planning of bicycle lanes and facilities, i.e. by combining short routes with circular routes that allow scenic and historical areas to be reached;
- Surveying the use patterns by demand group (e.g. tourists, commuters, residents, occasional users) could be beneficial to assess modification to the business structure;
- Strong cooperation with the bicycle manufacturer.

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PART 4. ANNEX. SCIENTIFIC PAPERS

Two scientific papers were published starting from the main contents presented in this report and from the data collected during the Moses pilot activities in Ravenna:

- “Flexible Mobile Hub for E-Bike Sharing and Cruise Tourism: A Case Study” published on 2 October 2019 on “Sustainability” Journal;
- “Innovative electric bike-sharing services for the promotion of sustainable connections among small touristic ports and inland: the Ravenna port case study”. Under publication on “Società Italiana di Economia dei Trasporti e della Logistica, XXI Riunione Scientifica, Bologna, 9-10 Settembre 2019”.