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HYBRIDIZING BIKE-SHARING SYSTEMS: THE WAY TO IMPROVE MOBILITY IN SMART CITIES

Abstract

New generation of bike-sharing systems introduce a wide range of smart solutions. Dockless bicycles equipped with GPS and accessible by smartphone applications as well as electric bikes are considered to be solutions to many socioeconomic and environmental urban problems. However, older generation of bike-sharing systems equipped with dockings stations have some advantages over free floating public bicycles. The aim of this paper is to examine if hybridization of both systems may become an opportunity to improve bike-sharing services. The paper presents characteristics of both types of bike-sharing schemes and describes the examples of hybrid models to show benefits of this solution. Chosen methodology is the case study of selected European bike-sharing systems which combine features of both schemes – the dockless and the station-based.

Keywords: smart city, smart mobility, dockless bike-sharing, station-based bike-sharing, hybrid bike-sharing

Introduction

Bike-sharing systems are widely discussed in the literature due to their ongoing expansion and improvement (Brunner, 2018, p. 4; García-Palomares, Gutiérrez, Latorre, 2012, p. 235; Li et al., 2017, p. 773). The idea firstly came up in '60s and '70s, overcame some failures, to finally become very popular around the world (Chiariotti et al., 2018). Recently the most significant changes in bike-sharing has been introduced by Chinese operators who invented and popularized dockless systems (Zhang, Lin, Mi, 2018, p. 383). Simultaneously cities are trying to handle various socioeconomic and environmental problems such as a traffic congestion, smog

and greenhouse emissions, noise pollution, diseases and inadequate space management (Chen et al. 2018, p. 6, Zhang, Lin, Mi, 2018, p. 383). Examples of solutions are the Smart City concept (Benevolo, Dameri, D'Auria, 2015, p. 13) and the Sustainable Urban Mobility Planning (Okraszewska et al., 2018, p. 479). Modern bike-sharing system equipped with GPS tracking, e-bikes and other ICT solutions already became a key smart city service (Chiariotti et al., 2018). Moreover it is commonly identified as a crucial tool changing passengers transport behaviour into the environmental friendly (Mortkowitz, 2018). The article purpose is to identify the challenges and the opportunities resulting from the new, dockless generation of bike-sharing for system planners in cities where the station-based systems are already functioning with success. It is also to underline the important role of the bike-sharing in the Smart City concept. The thesis of the article is that it is possible to hybridize two types of bike-sharing systems, the station-based and the dockless, to achieve the benefits of both while lessening the defects of each.

The methodology used in this paper is case study of the European cities where the hybridized bike-sharing systems are in operation or under construction. The first chapter of the article presents the history of the bike-sharing with special emphasis on the newest, dockless generation of the system. The second chapter includes the description of the smart city concept, as well as "smart" characteristics of bicycles and bike-sharing schemes. Finally it focuses on the comparison of station-based and dockless systems to underline the advantages and disadvantages of both. The third chapter is the case study analysis.

Bike-sharing as a smart service

The idea of the public bike was invented in Europe. In 1965 The White Bike (the Witte Fietse) programme was introduced in Amsterdam, the Netherlands. White painted bicycles delivered on the streets by municipal activists are considered to be the first generation of bike-sharing system, which collapsed quickly due to the lack of payment and security mechanisms. The main reason for the failure were numerous thefts and vandalism (Fishman, 2015, p. 94).

After about 30 years of little growth the second generation of bike-sharing system appeared in Denmark. Aside from two small systems launched in Farsø and Grenå (1991) and in Nakskov (1993), the first large-scale system was introduced in Copenhagen (1995). This public bicycles rental was based on a coin deposit system working similar to supermarkets' trolleys. The system differed from the first generation scheme also by docking stations and bicycles specially designed for intense use, with advertising plates on wheels. Unfortunately introducing a payment scheme and other improvements was not enough to avoid thefts caused mainly by anonymity of the user. This led to the rise of the next, third generation of bike-sharing (DeMaio, 2009, p. 42).

The beginning of the third generation of bike-sharing systems is dated to 1996 when the Bikeabout Programme was launched at Portsmouth University in England. Solutions used in this and following systems made the idea of public bikes a smart one. Firstly, bikes could be rented by using a magnetic stripe card. Next

systems brought additionally electronically-locking racks and bike locks. Bike-sharing systems started to be based on the telecommunication technology, providing bicycles accessible by smart cards, fobs and mobile phones as well as equipped with on-board computers. First big third generation system was developed in France – Lyon (1.500 bikes and 15.000 registered users in 2005). After the success of the Paris bike-sharing programme called Vélib', which had started two years after Lyon with 7.000 bicycles and reached an amount of 18.200 vehicles in 2017, the intensive expansion of the intelligent bike-sharing systems all over the world took place. In 2008 the bike-sharing started to be finally implemented outside the Europe, firstly in Brazil, Chile, China, New Zealand, South Korea, Taiwan, and the United States. Today it is easier to show the scale of this expansion on a map, presented in Figure 1.
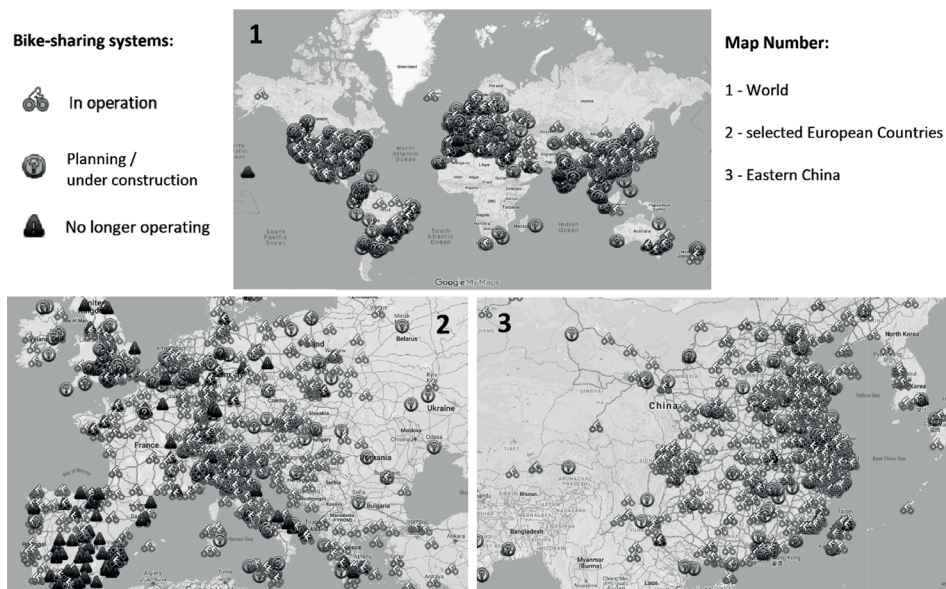

Figure 1. The Map of Bike-Sharing Systems as of October 2018
Source: (own elaboration based on: The Bike-Sharing World Map, 2018)

The Map of Bike-Sharing Systems showed in Figure 1 is a proof that popularity of the service exploded in last few years. This unquestionable worldwide expansion is to a great extent a result of the development of the new (fourth) generation of bike-sharing systems, that has recently begun in China. In 2015 dockless bikes with smart lock system accessible by smartphone application had been deployed on the streets of Chinese cities. Smart technological solutions and funding scheme based mainly on private investment led to the increase of the size of the Chinese bike-sharing fleet from 1.036 million to 23 million bicycles in only two years (Bieliński, Ważna, 2018). The number of registered users of bike-sharing rose from 28 million in 2016 to 400 million in 2017. Moreover there were 77 companies renting public bikes in more than 200 Chinese cities and towns at the end of 2017 (Bianji, 2018).

Dockless bike-sharing services have given a range of new opportunities for passengers and has influenced their transport behaviour. These innovative, smart solutions have also made bike-sharing systems easier to manage. Global Positioning System (GPS) tracking and mobile payment via smartphone applications are the key technologies changing the idea of shared public bikes, making this kind of service more accessible, transferable to other transport systems and finally – popular in more and more places (Shi et al., 2018, p. 2). The crucial steps in bike-sharing history which made the idea a smart service were presented in the Figure 2.
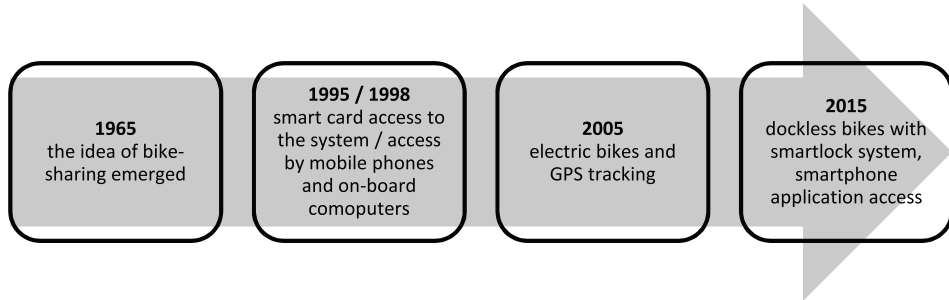

Figure 2. The history of making bike-sharing a smart service
Source: (own elaboration)

It is important to underline that the expansion of the fourth generation of bike-sharing outside China has already started. This process will continue, often causing the need to combine two types of bike-sharing systems. This is due to the fact that Chinese biggest bike-sharing companies, Mobike and Ofo, enter e.g. European markets in cities, where the station-based systems have been successfully working for many years (e.g. Amsterdam, Berlin, London and Paris) (Tchebotarev, 2017). What is interesting, not only Chinese innovative companies are entering markets in many countries, but the technology by itself is being adopted by local service providers, that used dockings systems before. This led to creation of hybrid schemes. Case studies of such bike-sharing systems were presented in the chapter 3.

The shape of bike-sharing systems has changed significantly in last few years and today we are still observing the process of dynamic development and transition on this market. Smart solutions have the crucial influence on this situation and determine the future of the bicycles role in cities.

2. Smart cities equipped with combined bike-sharing systems: challenges and opportunities

The Smart City concept is a widely discussed topic, which is perceived as a successful strategy to overcome major urban problems such as traffic congestion, pollution, energy consumption and waste treatment (Benevolo, Dameri, D'Auria, 2015, p. 13). There is no accurate definition of this idea, but it is often identified with intelligent, knowledge, ubiquitous, sustainable, green or digital city (Cocchia,

2014, p. 13). Smart City can be also described as a long-term and complex vision of an urbanised area, giving solutions to challenges of modern cities. ICT solutions are inseparable part of the Smart City and give support to all areas of urban life, including mobility (Benevolo, Dameri, D'Auria, 2015, p. 13). Therefore smart bike-sharing systems are considered to be a tool to achieve this smart vision of urban areas due to certain features of this kind of bicycles.

Main characteristics of bicycles make them a sustainable mean of urban transport. They are using no fossil fuels, producing no air pollution or noise. Additionally riding bikes has positive effects on health (Veryard, Perkins, 2017, p. 17). Basic advantages of bikes for short distance urban trips are:
– Possibility of making "door to door" trips,
– Requirement of less infrastructure and space in comparison to cars and public transport,
– Bikes are relatively inexpensive to purchase and maintain,
– Generally cyclists do not cause a traffic congestion (DeMaio, 2004, p. 2).

The idea of bike-sharing systems links listed benefits of bicycles with possibility to share public bikes and:
– Gives an opportunity to ride a bike while not having a private one,
– Makes changes to public means of transport easier and more comfortable,
– Gives a possibility to travel the "last mile" by bike instead of walking, what makes the trip faster (Shi et al., 2018, pp. 1–2).

In general all types of bike-sharing services give an accessibility to alternative for private cars and give more flexibility than scheduled public transport services (Veryard, Perkins, 2017, p. 17). The scale of the accessibility and the flexibility increases, when bike-sharing become dockless. Then users are not obliged to rent and return a bike at designated docking stations, but can find and leave it at any reasonable place. The dockless technology leads to problems with parking bicycles in inappropriate places like private properties, basements, active bike lines or narrow passages. Moreover similar travel patterns of most users cause the bike fleet imbalance especially during the rush hours. Too many bicycles at main city interchanges and lack of them in residential areas is only an example of this wide problem. Additionally the oversupply of dockless bikes occurs in many cities, especially in China, paralysing and congesting the public space (Ling, p. 1).

Both station-based and dockless bike-sharing schemes have their advantages and disadvantages. They were identified, and presented in the table 1. The dynamic growth of popularity of the newest type of bike-sharing does not mean that the station-based is going to disappear. Many cities all over the world with different set of cycling-friendly features (like infrastructure or bike-sharing service), will have to face the challenge of hybridizing two types of bike-sharing schemes in the nearest future or are even facing it at the moment (DeMaio, 2018).

Table 1. The comparison of station-based and dockless bike-sharing systems

Bike-sharing system type	Station-based	Dockless
Advantages	Docking stations provide an order in an urban area and help to keep the space well managed Provide a define set of locations where the trip can be started or finished Provide a level of comfort for users ensuring that bicycles are available at the same places every day	Enable clients to ride rented bicycles directly to their destination, and leave them where they want. Users are not obliged to plan carefully their trip, and/or find free space at docking stations Optimization of costs due to investment in bikes only, not in costly docking stations Enables bike-sharing companies to provide services in less dense urban areas
Disadvantages	Need for large number of docking stations to satisfy the needs of customers High costs of building, purchasing and maintaining docking stations Difficulties in finding and providing an acceptable and enough space to locate a station Users have to know the location of the station closest to their starting place or destination	The problem of inappropriate ways of parking occurs High cost of redistribution of bicycles from places where they accumulate, to destinations were there are needed by customers. Users can not be sure if the bike they want to rent is actually available (e.g. parked in a legal and accessible place)

Source: (own elaboration based on: DeMaio, 2018)

The idea of hybridizing is about finding the way to achieve the benefits of both bike-sharing types and optimise the service at the same time. Overcoming defects of each is also possible in this process. What is worth mentioning, the station-based systems are used more for "to work" and "from work" journeys, and dockless are used more frequently after work hours (McKenzie, 2018, p. 3). Knowing the differences between travel patterns concerning both types of bike-sharing, it could be even easier to implement the idea of hybridization, which should be based on the cooperation between municipalities and operators (DeMaio, 2018). Hybridization in practice may mean the introduction of a new type of service in cities, where the system based on stations has been functioning for years. Furthermore, it can take the form of a completely new system with features of both analysed schemes. The case study analysis of the second form of hybrid bike-sharing systems was presented in the chapter 3.

3. Case study of hybridized bike sharing systems

Cracow was the first Polish city to implement hybridized bike-sharing system called Wavelo. In the autumn of 2016, the first pilot party of bikes appeared on the streets of the city. The system was fully implemented in spring 2017, over 1500 two-wheelers and 162 stations throughout the city. In October 2018 the number of stations increased to 172 thanks to partnership agreements[1]. Bicycles can be picked form docking stations or directly from the streets. Mobile application enables users to find unused bicycles. After the usage, they can be left in one of the 172 docking stations or parked in any legal destination for additional fee of 3PLN. Users that would pick up such bike, and return it into the docking station gain 1PLN credit to their accounts (Wavelo, 2018). For leaving it outside of the system area there is a penalty fee of 100PLN, however user can leave that area, put their bicycles into a pause mode, and bring them back, paying just the standard fees. Although some users leave bicycles in improper locations (e.g. on private property), the system generally prevents inappropriate usage that occurs in some Chinese cities, where bicycles were in large numbers dumped blocking pedestrians pathways or metro entrances. Most of the bicycles are brought to the docking stations by their users. Additionally small team of Wavelo workers seek for the bicycles that were left out of the docking stations, and bring them to the destinations were the demand for bicycles is high (Dokąd jedzie Wavelo..., 2018, pp. 1–2). The system generally proved to be successful, with over one million of bicycle rentals, 380 thousand hours and 3,5 million kilometres cycled by its users since its deployment to 15th of May 2018 (Kraków, Milion wypożyczeń…, 2018).

Another example of Polish hybridized system is MEVO operated by Nextbike in Gdansk, Gdynia, Sopot and 11 neighbouring municipalities (planned commissioning at the end of 2018). This service is going to be the largest and most modern public bicycle system in Europe, delivering 4080 electric, dockless vehicles. Registered users will pay a maximum 10PLN fee for a month with the limit of 90 minutes per day of usage. The annual fee will be also introduced and it will be maximum 100PLN. Additionally there will be possibility to pay only for minutes of a ride, then the fee will be 0.10PLN/min. Same as in Cracow 3PLN fee will be charged for leaving bicycles outside docking stations (Mevo, 2018).

Bike-sharing systems outside Poland, in the biggest European cities, are often more developed and based on the offer of more than one operator. In October 2018 in Berlin were functioning seven bike-sharing services including station-based Nextbike system and a few dockless ones. One of them is the Donkey Republic system operated by the company from Copenhagen. This bike-sharing service is classified as a dockless simply due to the lack of docking stations, but has some features characteristic for hybridized scheme. Registered users who want to rent a Donkey Republic vehicle can locate a free bicycle by a smartphone application, find it and open using the QR code. There is a limit of maximum 5 bikes being rented at once. What is important, these bikes can be only left at the original location, except when the user pay an additional fee for leaving it anywhere else. Designated "drop-off

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[1] An example of partnership agreement: a company e.g. retail store can sponsor docking station and appoint its localization to serve its clients or staff members.

locations" function partly as a docking-stations. This solution enables proper fleet management. The price of a regular rental is 1.25 EUR/30 min, maximum 10 EUR/day (The Ultimate Guide…, 2018). The Donkey Republic bike-sharing services are also provided in cities such as: Amsterdam, Barcelona, Budapest, Copenhagen, Munich, Paris, Rotterdam, Vienna (in over 40 cities in total) (Donkey Republic, 2018).

Another example of innovative and hybrid bike-sharing scheme is the system recently opened in Edinburgh, provided by Serco company and named Just Eat Cycles. The basic innovative technology which connects the idea of station-based and dockless bike-sharing schemes within the Edinburgh's system is a smart hybrid lock. It gives a possibility of leaving the bicycle at the docking station or at the designated dockless parking areas without any bike racks. The procedure of finding, hiring and returning a bike is quite similar to the Wavelo scheme described above. From September 2018 the initial 200 bicycles are available for citizens, and the fleet is planned to grow to 1000 bikes till the end of the year. In 2019 another 100 electric will be added to the system. Serco is cooperating not only with Transport for Edinburgh (TfE – the governmental unit), but also with e.g. The University of Edinburgh and private landowners, to create the initial network of locations across the city. There are three ways to hire a bike in this system. Firstly, users can have an annual membership for 90GBP that enables them to cycle 60 minutes a day. Secondly, it is possible to buy a day subscription for 3 GBP for 24 hours of unlimited journeys per day, every of which can last maximum one hour. Finally, the single trip costs 1.5 GBP for up to an hour (Just Eat Cycles, 2018). The Just Eat Cycles is the first hybridized bike-sharing system in the UK (Transport for…, 2018).

Conclusions

The case study and the literature review led to the conclusion that both the third as well as the fourth generation of bike-sharing systems are an important part of the Smart City concept. The station-based and the dockless bike-sharing schemes have their own advantages and disadvantages. Analysed examples of existing hybrid systems proved the thesis that the hybridization is possible, and helps to achieve the benefits of both types of the system while lessening the defects of each. Positive consequences of the introduction of hybrid systems are:

Users of the system have a choice if they want to leave a bicycle at a docking station or at any other location in which they can legally leave rented vehicles – from the customer point of view the system is more flexible.

Users often can find a bike closer to their starting place than the nearest docking station is located.

In case of lack of available bicycles left outside the stations, it is more likely to find one at the nearest docking station, what gives the user a level of comfort while planning a journey.

Users can leave the bicycle at the docking station even if there are no free bike racks. Very often it is enough to leave the two-wheelers locked near the station.

The problem of bike fleet redistribution in the city is not as big as it is without docking stations. It is due to the additional fee for leaving the bike outside

the docking station – users prefer to give bicycles back to the stations. They can also be encouraged by financial incentives to take bicycles back to stations.

It is easier to manage properly the bike-sharing system as the travel patterns of each type of bike-sharing service differs. Moreover system operators can provide the fleet of bikes to locations where the demand is higher, without additional, high costs of building a new docking stations.

Docking stations support providing electric bikes within the city, because they can have a function of a charger.

Summarising the article it is important to underline that the hybridization of the station-based and the dockless public bikes can have different forms. It is possible to introduce hybrid system as a new, comprehensive service. System operators can also successfully integrate the existing station-based service with the dockless technology. This however, might be more difficult, as it requires the cooperation between systems' operators and municipalities. Moreover, the competition between vendors must be taken into account. Nevertheless, the hybridization is worth introducing and in many cities all over the world may be inevitable due to the spread of the dockless technology.

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