UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ETS INGENIEROS DE CAMINOS, CANALES Y PUERTOS

TRABAJO DE FIN DE MASTER

Dockless Bike-sharing Systems in Future Sustainable Cities - Research and Possible Applications in Budapest and Valencia

Sistemas de Bicicletas compartidas en las ciudades sostenibles en el futuro - Investigación y aplicaciones posibles en Budapest y Valencia

Presentado por

Radics, Miklós

Para la obtención del

Master Universitario en Transporte, Territorio y Urbanismo

Curso: *2017/2018*

Fecha: *10 de julio de 2018*

Tutor: *Sánchez, Tomás Ruiz*

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Dockless Bike-sharing Systems in Future Sustainable Cities –
Research and Possible Applications in Budapest and Valencia

Abstract

The aim of my research is to identify the hidden possibilities and advantages of new generation free-floating, dockless public bike-sharing systems and multi-operator models. I assume that the new approach brought by the dockless technology boom could accelerate the spreading of bike-sharing services as these schemes provide more flexible and accessible services. Based on international practices and market liberalization examples in the transport sector, I propose a general regulatory framework which could ensure a high-quality service by maximizing the benefits and eliminating the possible drawbacks of the new generation schemes and operating model.
To complement the desk research, I carried out stakeholder interviews to understand better the opinions of Hungarian and Spanish planners, bike-sharing operators, decision makers and NGOs. I examined the bike-sharing services of Budapest and Valencia to apply the findings and results of the thesis. I set up recommendations for both cities to improve their bike-sharing services, preferably with dockless technology.

Bike-sharing plays a great role in promoting urban cycling and sustainable mobility. It provides the possibility to all to use a bicycle whenever it is the most convenient way to get from A to B. As it has a wide range of benefits, in recent years bike-sharing has become popular all around the world and many cities have developed their own systems.
Last year news about the dockless bike-sharing boom of China hit the European and global media. Photos about bikes flooding the streets and sidewalks of Chinese cities went viral. Oversupply, vandalism, parking problems occurred because of low market entry barriers and lack of agreement between cities and bike-sharing operators. As cities realized that they had to take actions to avoid these problems they started to set up recommendations to regulate the services of new private operators funded by venture capitals. For now, more than 30 cities around the world have their own recommendations to maximize the benefits of dockless bikes while preventing the negative effects of unregulated market competition.

The negative reputation of dockless systems contributed to the degradation of their image and the technology itself among users, citizens as well as among decision makers and politicians. To have a clear picture, we should study the hidden possibilities and opportunities of dockless systems with an objective approach. In my research I give an overview of these factors and of the tools which can help cities maximize the benefits of dockless systems.

Keywords

Sustainable urban mobility, Bike-sharing systems, Dockless, Regulations

Sistemas de Bicicletas compartidas en las ciudades sostenibles en el futuro - Investigación y aplicaciones posibles en Budapest y Valencia

Resumen

Los objetivos de la investigación son identificar las posibilidades y las ventajas ocultas de la nueva generación de las bicicletas públicas sin anclaje *(dockless, free-floating)* y del modelo de múltiples operadores. Cabe destacar que el nuevo enfoque aportado por el auge de las bicicletas sin anclaje, podría acelerar la difusión de los sistemas de bicicletas compartidas obteniendo servicios más flexibles y accesibles. Sobre la base de las prácticas internacionales y ejemplos de la liberalización del mercado en el sector del transporte se propone un marco regulatorio que podría garantizar un servicio de alta calidad maximizando los beneficios y eliminando los posibles inconvenientes de los esquemas de la nueva generación y del nuevo modelo operativo.
Para complementar la investigación documental se realizan entrevistas para entender mejor las opiniones de los planificadores húngaros y españoles, los operadores de bicicletas compartidas, los tomadores de decisiones y las ONG sobre las bicicletas compartidas y sobre la nueva tecnología. Para aplicar los hallazgos y los resultados de la tesis se examinan los servicios de bicicletas compartidas de Budapest y Valencia. Además, se proponen recomendaciones para ambas ciudades para mejorar los servicios de bicicletas compartidas, preferiblemente con la tecnología sin anclaje.

Las bicicletas compartidas juegan un gran papel en la promoción del ciclismo urbano y la movilidad sostenible, ofreciendo la posibilidad a todos los usuarios de usar una bicicleta cuando sea necesario. Como los sistemas tienen una amplia gama de beneficios las bicicletas compartidas han ganado gran aceptación en todo el mundo y muchas ciudades han desarrollado sus propios sistemas.
El año pasado las noticias sobre el auge del uso bicicletas públicas sin anclaje en China llegaron a los medios europeos y mundiales. Las fotos sobre las bicicletas inundaron las calles y las aceras en las ciudades chinas, volviedose virales. La sobreoferta, el vandalismo y los problemas de aparcamiento ocurrieron como resultados de las bajas barreras de entrada al mercado y de la falta de acuerdo entre las ciudades y los operadores de bicicletas sin anclaje. Cuando las ciudades se dieron cuenta de que tenían que tomar medidas para evitar los problemas, comenzaron a establecer recomendaciones para regular los servicios de nuevos operadores privados financiados por capitales de riesgo. Por ahora, más de 30 ciudades de todo el mundo tienen sus propias recomendaciones para maximizar los beneficios de las bicicletas sin anclaje mientras previniendo los efectos negativos creada por la competencia no regulada del mercado.

La reputación negativa de los sistemas sin anclaje contribuyó a la degradación de su imagen y de la tecnología entre los usuarios, los ciudadanos y entre los tomadores de decisión y los políticos. Para tener una idea clara, deberíamos que estudiar las posibilidades ocultas y las oportunidades de los sistemas sin anclaje con un enfoque objetivo. En mi investigación doy una descripción de estos factores y de las herramientas que pueden ayudar a las ciudades a maximizar los beneficios de los sistemas de bicicletas públicas sin anclaje.

Palabras clave

Movilidad urbana sostenible, Bicicletas compartidas, Bicicletas sin anclaje, Regulación

Sistemes de Bicicletes compartides sense ancoratge en les Ciutats sostenibles en el futur- Investigació i possibles aplicacions a Budapest i València

Resum

Els objectius de la investigació són identificar les possibilitats i els avantatges ocultes de la nova generació de les bicicletes públiques sense ancoratge (dockless, free-floating) i del model de múltiples operadors. Cal destacar que el nou enfocament aportat per l'auge de les bicicletes sense ancoratge, podria accelerar la difusió dels sistemes de bicicletes compartides obtenint servicis més flexibles i accessibles. Sobre la base de les pràctiques internacionals i exemples de la liberalització del mercat en el sector del transport es proposa un marc regulador que podria garantir un servici d'alta qualitat maximitzant els beneficis i eliminant els possibles inconvenients dels esquemes de la nova generació i del nou model operatiu
. Per a complementar la investigació documental es realitzen entrevistes per a entendre millor les opinions dels planificadors hongaresos i espanyols, els operadors de bicicletes compartides, els acceptants de decisions i les ONG sobre les bicicletes compartides i sobre la nova tecnologia. Per aplicar les troballes i els resultats de la tesi s'examinen els servicis de bicicletes compartides de Budapest i València. A més, es proposen recomanacions per a ambdós ciutats per a millorar els servicis de bicicletes compartides, preferiblement amb la tecnologia sense ancoratge.
Les bicicletes compartides juguen un gran paper en la promoció del ciclisme urbà i la mobilitat sostenible, oferint la possibilitat a tots els usuaris d'utilitzar una bicicleta quan siga necessari. Com els sistemes tenen una àmplia gamma de beneficis les bicicletes compartides han guanyat gran acceptació en tot el món i moltes ciutats han desenvolupat els seus propis sistemes.
L'any passat les notícies sobre l'auge de l'ús bicicletes públiques sense ancoratge a Xina van arribar als mitjans europeus i mundials. Les fotos sobre les bicicletes van inundar els carrers i les voreres en les ciutats xineses, tornant-se virals. La sobreoferta, el vandalisme i els problemes d'aparcament van ocórrer com resultats de les baixes barreres d'entrada al mercat i de la falta d'acord entre les ciutats i els operadors de bicicletes sense ancoratge. Quan les ciutats es van donar compte que havien de prendre mesures per evitar els problemes, van començar a establir recomanacions per a regular els servicis de nous operadors privats finançats per capitals de risc. Per ara, més de 30 ciutats de tot el món tenen les seues pròpies recomanacions per a maximitzar els beneficis de les bicicletes sense ancoratge mentres prevenint els efectes negatius creada per la competència no regulada del mercat.
La reputació negativa dels sistemes sense ancoratge va contribuir a la degradació de la seua imatge i de la tecnologia entre els usuaris, els ciutadans i entre els acceptants de decisió i els polítics. Per a tindre una idea clara, deuríem que estudiar les possibilitats ocultes i les oportunitats dels sistemes sense ancoratge amb un enfocament objectiu. En la meua investigació done una descripció d'estos factors i de les ferramentes que poden ajudar a les ciutats a maximitzar els beneficis dels sistemes de bicicletes públiques sense ancoratge.

Paraules clau

Mobilitat urbana sostenible, Bicicletes compartides, Bicicletes sense ancoratge, Regulació

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Abbreviations

API	Application Programming Interface
BKK	Centre for Budapest Transport (Budapesti Közlekedési Központ)
B&R	Bike and Ride
BRP	Bike-sharing Rebalancing Problem
BSS	Bike-sharing System
CBA	Cost Benefit Analysis
ECF	European Cyclists' Federation
EU	European Union
EUR	Euro (€), the official currency of the European Union
FFBS	Free-Floating Bike-sharing
GBFS	General Bikeshare Feed Specification
GDP	Gross Domestic Product
GPS	Global Positioning System
HUF	Hungarian forint (Ft), the official currency of Hungary
ICT	Information and Communication Technology
INE	Spanish Statistical Office (Instituto Nacional de Estadistica)
IT	Information Technology
ITDP	Institute for Transportation and Development Policy
MaaS	Mobility-as-a-Service
MOL	Hungarian multinational oil and gas company (MOL Nyrt.)
MoU	Memorandum of Understanding
NABSA	North American Bikeshare Association
NACTO	National Association of City Transportation Officials
NYC	New York City
PBS	Public Bike-sharing
PEBBS	Platform for European Bicycle Sharing & Systems
PT	Public Transport
RFID	Radio-Frequency Identification
RQ	Research Question
UITP	International Association of Public Transport (L'Union internationale des transports publics)
UK	United Kingdom
UN	United Nations
SBBS	Station-Based Bike-sharing
SME	Small and Medium-sized Enterprises
SUMP	Sustainable Urban Mobility Plan
SWOT	Strengths, Weaknesses, Opportunities, and Threats analysis
TaaS	Transportation-as-a-Service
TfGM	Transport for Greater Manchester

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1 Introduction

This chapter discusses the background of the thesis, as well as the aims and main objectives. There is an introduction of the methodology and structure at the end of the chapter.

1.1 Problem description

According to the United Nations' data booklet, in 2016 an estimated 54,5% of the world's population lived in urban environment.[1] By 2030, urban areas are projected to accommodate 60% of the global population and one in every three people will live in cities with at least half a million inhabitants.[2] It is inevitable to understand the key trends and effects of urbanization and adapt to the changes. (1)
59% of the European Union's population lives in cities where 68% of GDP of the EU is produced with 62% of the jobs of the EU as a result of highly educated population, more innovation and higher productivity in urban areas compared to rural. (2) As urban environment and cities provide better living conditions, more opportunities for education, work and healthcare more and more people are moving into them while the suburbs are expanding as well.

As progressively more people use the urban infrastructure the pressure on it is steadily increasing and became one of main challenges of cities. The increasing volume of motorized transport has great negative effects on people's health and on the environment. Traffic crashes[3] cause more than 25 000 annual deaths in the EU and more than one third of them happen in cities. (3) Motorized traffic is one of the major sources of air pollution in urban areas. About 20% of total greenhouse gas emissions is caused by transport in the European Union while road traffic is the dominant source of environmental noise. (4) (5) (6)
Car oriented city development is associated with social erosion which threatens urban life. Inadequate accessibility within urban areas makes life harder for people with special needs and causes equity problems. (7) (8)

A quote of Jan Gehl, who is a world-famous leader in human focused urban design, points out the phenomenon which drives our daily life in cities: *"First we shape our cities and then they shape us"*. (7) Among researchers of urban design, it is well known that the quality of urban spaces has a great effect on urban life. Transport development effects urban structure and urban development and vice versa.
Mass motorization had great effects on urban development as cities, their structure and streets were designed for cars and motorized transport. This approach led to various social and urban problems such as city sprawl, transport dominated streets, lack of human activity and so on. In a welcoming, human scale urban environment and streetscape people tend to spend more time. Car-oriented streets do not attract people and social activities.
Cities should be redesigned to provide more space for people. Compact, dense cities attract walking and cycling, cities and their streets should be reshaped and public spaces should be redistributed to provide more space for sustainable urban mobility modes, such as more comfortable sidewalks, safe cycling network and proper public transport infrastructure.

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[1] In 2016 the world's population was estimated 7.4 billion people.
[2] By 2030 the world's population is estimated to reach 8.4 billion.
[3] It is widely discussed that *traffic accident* in general is a misleading term which presupposes that crashes are unavoidable. However, traffic crashes are fixable problems as the majority is caused by inappropriate street design and intoxicated, speeding, distracted or careless drivers. (184)
More info: https://www.vox.com/2015/7/20/8995151/crash-not-accident (Cited: June 9, 2018)
https://www.citylab.com/transportation/2015/09/why-we-say-car-accident-and-why-we-need-to-stop/403144/ (Cited: June 9, 2018)

Figure 1: The inequity of urban space in car-oriented cities (Source: Fabian Todorovic – Twitter[4])

These challenges are known for a long time and cities have started to react to them. One of the main strategic responses is called *2030 Agenda for Sustainable Development* by the United Nations, which addresses urban problems, among others, on a global scale. (9)
Climate change mitigation has become a driver objective on European level as well. To reduce the negative effects of motorized urban traffic, promoting cycling is in the focus of European transport and general policy. One of the main objectives of the *Europe 2020* strategy is *"Resource efficient Europe*" which means that use of renewable energy sources, modernization of the transport sector and energy efficiency should be enhanced by decarbonization of the transport sector and focusing on the urban dimension. (10) *White Paper on transport* states that for a cleaner urban transport and commuting, walking and cycling should be facilitated and should become an integral part of urban mobility and infrastructure design. (11) *Green paper* aims towards free-flowing cities, realizing the problem of congestions and other negative economic, social, health and environmental impacts of transport as well as the degradation of the natural and built environment caused by traffic. As a respond to these problems attractiveness and safety of walking and cycling should be improved. (12)
There are various solutions to address the problems mentioned above. The aim is a transport behavioral change by restricting car use and providing viable alternatives. Sustainable urban development and mobility planning is in the focus of decision makers, planners, citizens, NGOs and all other stakeholders who desire a better urban future.
The methodology of sustainable urban mobility planning (SUMP) and the recommended measures[5] are effective tools to enhance the use of sustainable mobility modes such as walking, cycling and public transport. (13)
Promoting cycling, as an environmentally friendly transport mode, is an obvious solution which is becoming increasingly widespread. Bike-sharing systems take one step further as they provide the same benefits as cycling, but in a more flexible and accessible way. Cycling and bike-sharing systems extend the catchment areas of public transport stops, which make sustainable multimodal journeys accessible for more people. (14) As promoting cycling and developing bike-sharing systems could play a great role in achieving the desired changes, they have become essential tools for cities.
Since the late 2000s, many cities have introduced bike-sharing systems to provide a sustainable mobility option for their citizens. In 2001 only 4 bike-sharing schemes operated, while the number in 2016 was almost 1200. Originally, these schemes which became popular worldwide, are mostly station based. People can pick up and drop off the bikes at automated stations throughout the city.

[4] https://twitter.com/fabiantodorovic/status/911286905538564098 (Cited: June 16, 2018)
[5] European Local Transport Information Service (ELTIS), http://www.eltis.org/ (Cited: June 9, 2018)

In recent years dockless bikes and private operators hit the Chinese and later the worldwide markets. Bike-sharing does not require stations anymore, the bikes can be left wherever the users want to leave them. These systems provide great flexibility for users and operators too. However, some new challenges have emerged with the new solution as well.
The technology and the key market actors of bike-sharing systems are changing now. One thing is clear, bike-sharing provides plenty of possibilities to tackle urban and transport problems. It is now up to us to make use of the new opportunities.

1.2 Aims and objectives

New dockless bike-sharing providers pop up in cities following new business models which requires new approaches from cities. Private companies and their investors want to make profit, so they expand rapidly. Parking problems, vandalism, oversupply occurred because of low market entry barriers and lacking agreements between cities and dockless operators. The technology of bike-sharing changes which creates new challenges for cities, decision makers and planners, while these changes offer new opportunities at the same time.
I assume that easy to implement and cheap dockless bikes could accelerate the spreading of bike-sharing schemes. The aim of my research is to identify the hidden possibilities and advantages of new generation free-floating, dockless public bike-sharing systems and multi-operator models. Besides that, I would like to propose a general regulatory framework for cities. The role of this regulation is to maximize the benefits and avoid the identified negative effects of dockless schemes. To apply the findings of my research, I would like to examine the bike-sharing services of Budapest and Valencia. I will propose future measures for both cities which could improve their bike-sharing services, preferably with dockless technology.
To achieve these aims I identified the main research questions (RQ) of the thesis.

RQ-1	How can cycling and bike-sharing systems contribute to the sustainable improvement of cities regarding urban and transport development?
RQ-2	Which are the main determinant factors of a successful bike-sharing system?
RQ-3	What are the main characteristics, advantages and disadvantages of new wave dockless bike-sharing systems?
RQ-4	How should cities treat the dockless bike-sharing boom and their rapid expansion? Would market liberalization and multi-operator models be feasible options for bike-sharing? What kind of regulations and operating models would be necessary for a successful, small-scale market liberalization on city level? What are the possible risks of inaction?
RQ-5	What are the main differences between state-of-the-art, 4th generation, station-based bike-sharing systems and dockless ones? Do these technologies compete or rather complement each other?
RQ-6	What are the main characteristics of the bike-sharing systems in Budapest and Valencia? What should be improved to provide better bike-sharing services? Is dockless bike-sharing technology is a suitable option for these two cities?

Table 1: Research questions

1.3 Outline of the thesis

The structure of the thesis is defined by the research questions which were discussed above. The following table summarizes the outline of the thesis by the summary of the chapters and the research question(s) which is discussed within each chapter.

2. Literature review	
Summary	The chapter gives an overview of the main findings of the relevant scientific articles and other professional sources.
Discussed RQ	The chapter serves as a base for the research.
3. The role of cycling and bike-sharing systems in cities	
Summary	The chapter summarizes the role of cycling and bike-sharing systems in sustainable urban transport and spatial development. The chapter discusses individual, economic and social benefits of cycling as well.
Discussed RQ	RQ-1
4. Bike-sharing systems – overview	
Summary	The chapter introduces the concept of bike-sharing systems through their evolution regarding technological aspects and their spread. The chapter also discusses the main benefits and the key determinants of successful bike-sharing systems.
Discussed RQ	RQ-2
5. Dockless bike-sharing systems	
Summary	The chapter summarizes the implications of the dockless bike-sharing boom for cities. The recent trends of shared mobility and market liberalization, dockless bike-sharing operators and the arguments against dockless technology are discussed in the introductory subchapters. The second half of the chapter examines the recommended and existing actions related to regulations. The final subchapter outlines the analysis of dockless technology.
Discussed RQ	RQ-3 and RQ-4

6. Findings	
Summary	The chapter summarizes the findings and conclusions of the thesis. There are several solutions to provide bike-sharing services but there is no one solution that fits all. For a better understanding I carried out a comparative assessment of state-of-the-art 4th generation station-based systems and dockless ones. Besides that, this chapter introduces a multi-operator model for bike-sharing.
Discussed RQ	RQ-4 and RQ-5
7. Case studies	
Summary	The aim of the case studies is to examine whether dockless bike-sharing technology is a suitable option for Budapest and Valencia. The chapter analyzes the existing bike-sharing services and the two cities themselves. Based on the main findings of the previous chapters I set up recommendations on how to improve MOL Bubi in Budapest and Valenbisi in Valencia, preferably with dockless technology.
Discussed RQ	RQ-6

Table 2: The outline of the thesis

1.4 Methodology, scope and delimitations

I wrote this thesis during my exchange semester at the Technical University of Valencia (Universitat Politècnica de València). To collect information about bike-sharing systems and the spread of dockless bikes I carried out a comprehensive literature review including scientific researches and articles, planning guidelines and manuals as well as non-scientific articles and journals.
To complement the desk research, I carried out stakeholder interviews to get to know the opinions of Hungarian, Spanish and other international professionals on bike-sharing systems, especially on dockless ones. I interviewed representatives of bike-sharing operators and NGOs, decision makers, planners and consultants both from Budapest and Valencia to collect information for the case studies. Additionally, I did fieldwork to gain experiences and examine the bike-sharing systems and cycling infrastructure of the two chosen cities.
Based on the preparatory work detailed above, I carried out a SWOT analysis to identify the main characteristics of dockless bike-sharing services. Besides that, I made a comparative assessment of dockless and station-based bike-sharing technology.
To apply the findings and results of the thesis I set up recommendations and possible future developments to improve the bike-sharing services in Budapest and Valencia, preferably with dockless technology.

During my work I faced some limitations as well.

As the dockless bike-sharing boom is a recent phenomenon, limited data resources and published researches are available. Consequently, it is difficult to carry out quantitative analysis about the new generation of bike-sharing services. However, the media and daily news have been focused on the spread and performance of dockless bike-sharing systems since the beginnings. Besides that, the debate on dockless bike-sharing systems is broadening among professionals and decision makers as well.

In this research I focused on dockless bike-sharing systems related policies and regulations. While I was studying international examples, I realized that other shared mobility modes faced similar problems. The examined and proposed regulatory framework for dockless bike-sharing services in the future should be extended with a more complex approach to involve other shared mobility modes and address public space consumption and mobility service integration in a more efficient way. As the topic of my research and the given timeframe was limited, the detailed regulatory recommendations focus only on dockless bike-sharing.

Another limitation I faced was to understand the user needs and satisfaction regarding the bike-sharing services of Valencia and Budapest. At first, I wanted to create and share a questionnaire to examine the bike-sharing services and cycling conditions in both cities. As I had limited resources to cover a representative sample, I realized it would not have been the best option to collect information. It would have been too long and resource-intensive. Fortunately, I found several other resources which provided a proper base for my research. However, I created a proposal for the structure of the questionnaire which can be used to monitor the impacts of the proposed measures (see chapter No. 0).
As I wrote my thesis as an exchange student in a new city, it was also challenging to get to know local professionals who are responsible for the decisions and operations of Valenbisi. Getting in touch with local experts took me relatively long while I had limited time to work on the case studies. Therefore, the recommendations for Valencia are not as detailed as the recommendations for Budapest which is a city I know better.

1.5 Inspiration and personal background

I have been always interested in cycling. When I was a child I loved to cycle. I have some great memories about my cycling experiences from my childhood which I hope I will never forget. When I became older I fell in love with cycling touring and I started to discover Hungary and Europe on two wheels.
Cycling has always been a major option for me to get from A to B. When I started my university studies I moved to Budapest where I got to know the "urban cycling movement". During that time, I had to learn the rules of cycling in a metropolis where bicycle-friendly conditions only partly existed. I realized that cycling was the most efficient way to get around Budapest – just like earlier in my hometown. As my studies went on, I have become interested in sustainable urban mobility and cycling. After I finished my bachelor studies I got the opportunity to work for the Hungarian Cyclists' Club. I decided to get familiar with cycling activism and be part of the Hungarian cycling movement. Since then, I have learned a lot about cycling and its many aspects, such as bicycle-friendly infrastructure development, promotion, marketing, legislation etc.
I believe that cycling is one of the greatest and most complex tools to fix urban and mobility problems as it creates better, more livable environment in our cities. Bike-sharing is a good opportunity to show people how cycling works and how beneficial it could be in a lot of cases. With this research I would like to increase my knowledge about bike-sharing services, study their future and their possible development. To make my thesis useful on a larger scale I decided to apply my findings in the cases of Budapest and Valencia to improve bike-sharing services in both cities.

2 Literature review

In this chapter I briefly summarize the main findings of relevant scientific articles and other professional sources which serve as a base for my research.

As the dockless bike-sharing system boom is a recent phenomenon only a few scientific articles are available about it. However, it is easy to find journal articles, professional statements and other informal, non-scientific documents about dockless bikes.
Most of the researches I found focused on traditional, station-based technology. I searched for the articles using on-line tools such as ScienceDirect[6], Google Scholar[7], Academia[8] and ResearchGate[9] using bike-sharing related search terms. The most common topics which are discussed in the researches I found are the benefits of cycling and bike-sharing systems, rebalancing problems, user satisfaction aspects and planning guides.
Some articles provide a general overview about bike-sharing related literature and systems' performance. A review encompasses researches published between 2013 and 2015, and another one the most important researches published before 2013. (15) (16)

2.1 Benefits of cycling and bike-sharing systems

It is widely accepted that regular cycling and bike-sharing, as active mobility modes, have great positive effects on personal well-being, health and productivity, while cycling network development and higher modal share of cycling reduce the transport sector's negative environmental impacts and contribute to economic development. (15) (17) Moreover, bike-sharing popularizes cycling, improves its reputation and encourages cycling as it brakes the subcultural image of cycling. Shared bicycles are used by everyday people and bike-sharing has the potential to increase the visibility of people cycling in everyday clothes.[10] This effect eliminates the stereotypes like *'cycling is risky'* or *'cycling is only for sporty people'*. (18)

Bike-sharing systems can make a change towards more sustainable urban mobility and influence travel patterns by providing easy access for cycling and fostering multimodal trips. In large, dense cities bike-sharing services provide a quick, cheap and direct connection for shorter distances normally travelled by walking or public transport. For longer distances bike-sharing serves as an important first and last-mile connector and increases public transit use. It bridges gaps in existing transportation networks. (14) (19) (20)
A research concludes that CityBike in Vienna functions as a supplement of the local public transport services rather than competing with it. The bike-sharing systems are more likely to be used where the public transport trip takes around twice as long. (21)
Various researches examine the effects of bike-sharing systems on travel behavior and travel patterns. Some articles conclude that bike-sharing trips replace former public transport and walking trips. (22) (23) Other papers found that a shift from the private car occurs only for a minority of bike-sharing trips and bike-sharing is mostly used to substitute walking or public transport trips. (24)

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[6] https://www.sciencedirect.com/ (Cited: June 4, 2018)
[7] https://scholar.google.com/ (Cited: June 4, 2018)
[8] https://www.academia.edu/ (Cited: June 4, 2018)
[9] https://www.researchgate.net/ (Cited: June 4, 2018)
[10] There are various aims to popularize and make cycling fashionable. One of the well-known movements is Cycle Chic as there are more than 100 blogs worldwide with the same brand. Copenhagen Cycle Chic, the first blog, was started in 2007 by Mikael Colville-Andersen. http://www.copenhagencyclechic.com (Cited: June 11, 2018)

The project report of the FLOW project[11], whose aim was to define the role and assess the impacts of cycling and walking on congestion reduction, concludes that walking and cycling improvement projects significantly reduce congestions. (25) (26)

Policies which encourage active mobility (walking and cycling) have been related to health benefits in six European cities. This kind of policies contributed to the reduction of carbon dioxide emissions and mortality related to physical inactivity or air pollution. (27)
A research with the involvement of almost 600 000 users analyzed data on travel, physical activity, road traffic collisions and particulate air pollution. It was found that London's bike-sharing had a positive overall health effect on the population. (28)
A health impact assessment of cycling network expansions in seven European cities found that the increase of cycling is beneficial for cities. Cycling network development was associated with an increase in cycling modal share which provides considerable health and economic benefits. Higher share of cycling avoids premature deaths caused by physical inactivity, air pollution and traffic accidents. Cost–benefit analysis showed that investment in cycling infrastructure generally has positive returns. (29)
Another study about the same cities found that urban cycling can help reach the WHO's physical activity recommendations. The results showed that almost 90% of those who uses their bicycles regularly as a mode of transport (identified as cyclists in the research) reached 30 minutes of daily moderate physical activity while this ratio was less than 30% among non-cyclists. (30)
A recent research with a new and unique approach analyzed the health benefits of twelve European BSS. The research identifies the effects of bike-sharing systems in terms of physical activity, road traffic fatalities and air pollution. The paper concludes that bike-sharing systems in Europe provide health and economic benefits therefore bike-sharing can be used as a tool for promoting health awareness and prevention. Promoting the use of bike-sharing systems by shifting from private car use have significant health benefits.
It was estimated that 5.17 annual deaths are avoided in case of the twelve BSS, corresponding to an annual saving of 18 million EUR. If all car trips were replaced by BSS trips, 73.25 deaths could be avoided each year (225 million Euros saving) in the twelve cities. (31)

2.2 Rebalancing problem

Free-floating bike-sharing systems' bikes with real-time GPS tracking provide the possibility of smart management and rebalancing. Rebalancing means reallocation of bikes referring to actual user demand. The optimization problem of rebalancing bikes in the case of station-based bike-sharing schemes has a broad literature. (32) (33) The main objectives of the rebalancing are: minimize unsatisfied demand (lack of free docks or lack of bicycles), minimize the total distance, time and effort of rebalancing. (34) Free-floating bike-sharing takes a further step and increases the scale of the rebalancing problem. (35) Incentivizing user-based redistribution and influencing travel patterns by offering discounts for those who contribute to rebalancing the bike-sharing system is a common practice. Especially in those cities where redistribution requires great efforts from operators. Hilly terrain is a typical example where less users ride uphill then downhill, in particular when bikes are not electric power assisted. Advertising this option through popular route planner applications can lead to a win-win situation. Users can get free rides to home meanwhile they rebalance the system which contribute to lower operating costs. (36)

[11] http://h2020-flow.eu (Cited: June 10, 2018)

2.3 Success and user satisfaction

There are several papers which examine the performance of operating bike-sharing systems to identify the key factors which lead to general satisfaction. Moreover, there is need for a methodology to compare the success of bike-sharing systems based on a common metric. Some models are based on independent variables related to system attributes such as station density and compactness, transport infrastructure, weather conditions and geography. There are other factors which are hard to compare but notable parameters to show success are: trips completed, emission reduction, level of road congestion, cycling modal share, number of intermodal trips (bike share and public transport) health, safety or social equity. (37) (20)
There are researches and methodologies available about how to identify the willingness of use and acceptance of future bike-sharing systems. A research about mobility habits and attitudes was carried out in Budapest as the first step of the implementation process of the local bike-sharing system. (38)
In Medellin a user-centered assessment was carried out to identify user experience. Based on the findings of the research several recommendations were laid out for improving the service, communication and promotion strategies of the system. (39)
Several main types of barriers are identified to bike-share such as convenience and safety concerns, competitive advantage with other modes, mandatory helmet legislation and sign-up process. (15) Those who have not used bikes before are considerably more sensitive to proper, bike-friendly street design. Docking station availability around homes and destinations is also a major issue. (22) (40)

2.4 Planning guides and manuals

There are several planning guides and manuals available which give an insight view to understand the principles of successful bike-sharing systems. There are various feasibility studies which can be found easily on the internet after a short search. I collected the best practices from Spain and Hungary.
The feasibility study and cost-benefit analysis of the bike-sharing in Budapest serve as good examples. (41) The proposal for joint actions is also available which highlights the importance of bike-friendly infrastructure development. (42)
The Spanish Observatory of Bike-sharing[12] (*Observatorio de la Bicicleta Pública en Espana*) provides information and carries out researches and data analyses about the Spanish bike-sharing sector. (43)
A handbook within the OBIS project was carried out in 2010 which is available in seven languages. The aim of the handbook is to give policy recommendations, highlight influencing factors on bike-sharing systems, to guide planning, implementation and optimization through case studies from Europe. OBIS consortium has carried out a broad analysis of bike-sharing systems. 51 schemes in 48 cities located in 10 European countries were included in the qualitative and quantitative analysis based on 2008 and 2009 data. Although the handbook was carried out almost a decade ago, most of its statements are still adequate and useful. (44)
The Institute for Transportation & Development Policy (ITDP) published its first bike-sharing planning guide in 2013. The document evaluates international best practice and gives a comprehensive overview about the planning procedure and the main elements of a bike-sharing system. (45) Besides that, ITDP recently published a guideline for cities to help them manage and optimize dockless bike-sharing systems. (46) In June 2018, ITDP launched its new bike-share planning guide at the Velo-city conference in Rio de Janeiro, Brazil. (47)
A study by Marie-Ève Assunçao-Denis examines the factors which are associated with the success or failure of four bike-sharing systems in North America. (48)

[12] https://bicicletapublica.es (Cited: June 12, 2018)

National Association of City Transportation Officials (NACTO) published the Bike Share Station Siting Guide in 2016. (49) Furthermore, chapter No. 4.2 gives a more detailed overview about how to plan a bike-sharing system.

2.5 Smart technology, system data analysis and visualization tools

There are several papers about smart solutions which facilitate the availability of the bikes (e.g. bike booking, route planner applications etc.). Reallocation and optimization of bikes is also a well-researched topic (travel pattern analysis, data analysis to optimize reallocation to avoid full and empty stations). (50)
There is an emerging trend of developing smart cities with efficient, eco-friendly, state-of-the-art solutions. Smart cities demand efficient mobility solutions including shared mobility and public bike systems. Although smart solutions could be successful tools, there are researchers who state that smart cities do not always contribute to sustainability and they should be aligned to lead to concrete sustainable outcomes. (51)

Analyzing bike-sharing data and usage patterns has several opportunities for further applications and research including support for maintenance, rebalancing optimization and cycle infrastructure planning or urban development. (52)
Under the North American Bikeshare Association's leadership General Bikeshare Feed Specification (GBFS) was adopted in November 2015, which is a standardized data feed for bike-sharing system availability. It is an open data source which makes real-time bike-sharing data feeds publicly available in a uniform format. As of May 2018, almost 100 cities, both station-based and dockless bike-sharing systems used this data format. (53) (54)
Ito World, a United Kingdom based company specialized in mobility data, launched a global bike-sharing data feed. According to the CEO of the company, their global bike-share data-feed will help connect potential users with providers easier around the world to get more people on bikes. One of the potential benefits is that data could contribute to identify safer and faster routes. An intelligent route planner considers the nearest stations and bike availability to provide the best option for users. Besides that, new riders could be reached through multimodal journeys as rarely or never cycling users can be encouraged to go on two wheels if the applications offer faster or cheaper combined routes including cycling. Moreover, route planner and bike-sharing applications could improve reliability of the services through promoting user-based rebalancing by rewarding them. (36)

The list of the potential applications to use the provided data is endless. For example, there are route planner applications which can calculate multimodal routes including bike-sharing. Combining the intelligence of journey planners and bike-sharing availability can greatly enhance the use of them. A good example is the route planning application of Budapest (BKK FUTAR[13]) which is based on real-time data including fleet and bike-sharing availability data. The users can choose according to their preferences between preferred modes (walking, cycling, bike-sharing and public transport – even the sub-modes can be selected [metro, tram etc.]). If the user chooses riding a bike or using bike-sharing he/she can set route choice preferences (bike-friendliness and distance)

There are several on-line maps and visualization tools which provide data about bike-sharing services. (15) Paul DeMaio started *The Bike-sharing World Map*[14] in 2007, a well-known source for information about the global growth of bike-share services. In 2010, Oliver O'Brien launched a *Bike Share Map*[15] which is an on-line visualization tool to illustrate

[13] BKK FUTAR route planner application http://futar.bkk.hu (Cited: June 16, 2018)
[14] http://www.metrobike.net/the-bike-sharing-world-map/ (Cited: June 10, 2018)
[15] http://oobrien.com/bikesharemap/ (Cited: June 10, 2018)

bike-sharing performance, bike availability and activity in cities. *Bike-sharing Atlas*[16] is part of an ongoing research project of the Visualization and Data Analysis Group at the University of Vienna. (55)

2.6 Achieving social equity in bike share

Social benefits and social equity of bike-sharing systems are in the scope of researchers and policy makers. Bike-sharing provides a less-costly mobility option for those who could not afford other alternatives. As it was discussed before, bike-sharing has the potential to popularize cycling by eliminating the stereotypes of *'cycling is risky'* or *'cycling is only for sporty people'*. (18)
In several countries where the share of cycling is lower, it is considered as a mode of transport of younger or low-status people who do not have access for cars. This attitude is different in countries where the share of cycling is higher and cycling habits do not depend on gender, age, social or economic status. (56)
There are researches which found that bike-sharing can lead to a greater likelihood of cycling among those who live in the service area (Quebec, Canada). (57) However, others found contrary results as females and residents living out of the service area were underrepresented among all users (London, UK) although the paper concludes that expanding the bike-sharing service area into more deprived areas could improve equitable uptake. (58) It should be noted that the cited studies were published in 2012 and 2013, a few years after the bike-sharing systems were launched.
NACTO published a paper highlighting the essentials for an equitable bike-sharing system such as bicycle-friendly street and urban development, safety, promotion, attractiveness and integrated planning approach concerning socio-economic aspects. (59) Moreover, NACTO published a series of practitioners' papers about bike-sharing systems' equity concerns. (60)
The recently emerging trends of electric assisted shared bikes may contribute to social inclusion by providing a cycling alternative which tackles with topographical and distance barriers. (56)

2.7 The future of bike-sharing services

The following emerging trends shape the future of bike-sharing services: spread of electric pedal-assisted bicycles, developing data analysis methods and their gaining importance in the bike-sharing sector (see chapter No. 2.5), integration with public transport services and with other mobility options like the concept of MaaS[17], and expanding privately funded dockless technology and new business models. (56) (15)

[16] http://bikesharingatlas.org (Cited: June 10, 2018)
[17] *"Mobility-as-a-Service (MaaS), also known as Transportation-as-a-Service (TaaS), describes a shift away from personally-owned modes of transportation and towards mobility solutions that are consumed as a service. This is enabled by combining transportation services from public and private transportation providers through a unified gateway that creates and manages the trip, which users can pay for with a single account. Users can pay per trip or a monthly fee for a limited distance. The key concept behind MaaS is to offer both the travelers and goods mobility solutions based on the travel needs."* (Source of the definition and more information: Wikipedia - Transportation as a Service, https://en.wikipedia.org/wiki/Transportation_as_a_Service, Cited: May 22, 2018)

3 The role of cycling and bike-sharing systems in cities

In this chapter I briefly summarize the role of cycling and bike-sharing systems in sustainable urban transport and spatial development. The chapter discusses individual, economic and social benefits of cycling as well. The discussed research question is as follows.

RQ-1	*How can cycling and bike-sharing systems contribute to the sustainable improvement of cities regarding urban and transport development?*

Realizing the negative environmental and socio-economic effects of mass motorization, rapid urbanization and sedentarism, various international organizations suggested and requested the implementation of policies which foster developments for active mobility as well as further actions which encourage people to walk, cycle and use public transport more (as they have wide range of benefits, see chapter No. 2.1). (31)
Non-governmental organizations, civil movements and cycling lobby have emerged in the past decades which have had great successes and have earned reputation. As a result, various declarations, agreements and strategies were proposed on European and global level. Plenty of actions were taken on national level as well to promote cycling and to create favorable conditions and policies for active mobility. (56) One of the recent actions is the *EU Cycling Strategy* which was elaborated by a Europe-wide working group led by the European Cyclists' Federation. (61)
Promoting cycling with events, campaigns and with other marketing tools have become popular too. Bicycle parades, "Bike to work", "Bike to school" and other promotion campaigns, car-free days and the European Mobility Week have become essential tools and regularly organized events by NGOs as well as by private and public actors.
As a result, cycling is getting more and more popular all around the world after it had lost its important role in urban mobility in the last century due to motorization. The popularity of urban cycling is significantly growing worldwide. Unfortunately, the latest available EU-wide comparable data about cycling habits is from 2014 (see figure below). It shows that after the Netherlands and Denmark, Hungary had the third highest share of cycling as 22% of the population used bicycle most often on a typical day. The EU28 average was 8%, and the share of cycling in Spain was around 3% in 2014.

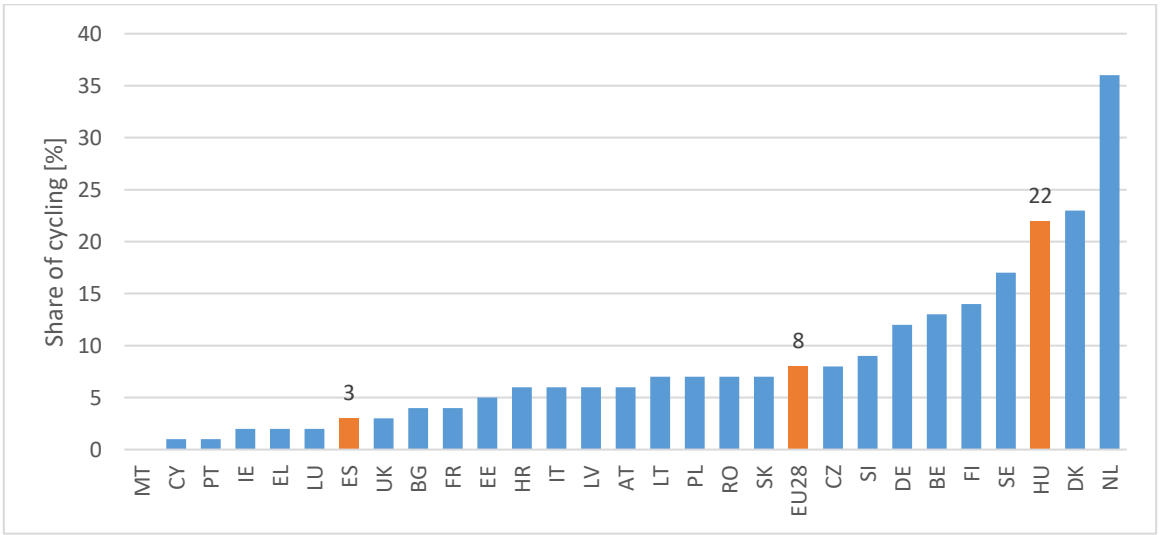


Figure 2: Share of cycling in EU28 countries in 2014
(Survey question – 'On a typical day, which mode of transport do you use most often?')
(Source of data: (62))

As the popularity of cycling is increasing rapidly, frequent data report would be needed for understanding the trends better and more. Lack of data about cycling is a widely-known barrier for researchers. Unfortunately, reliable and comparable data is hardly available for deeper analysis or comparison. (56)
Besides policy drivers, cycling is popular because of its wide range of benefits and various influencing factors such as individual motivations and social trends. (56)

Cycling is popular because it is a cheap and reliable way to get from A to B. Moreover, it is a sustainable, zero-emission, silent and healthy mode of transport which provides door-to-door mobility option for people. It is accessible, as riding a bicycle does not require a driving license or any special qualification or certificate. However, proper bike-friendly urban environment and transport system are essential to make cycling a favorable and accessible option for everyone (e.g. extensive cycling network, proper parking and B&R facilities etc.). Urban structure and dimensions as well as topology play an important role. Compact, dense cities provide favorable conditions and distances for cycling rather than car oriented, large-scale cities.
In cities, where most of the trips are short, cycling is faster than walking, public transport or private cars. It I estimated that up to 5 km cycling is the fastest mobility mode in urban environment. (63) (64) Cycling enhances multimodal journeys as it solves the first and last mile problem by filling the gap between homes and public transport stops. Compared to motorized vehicles it is also easier to park and store bicycles.

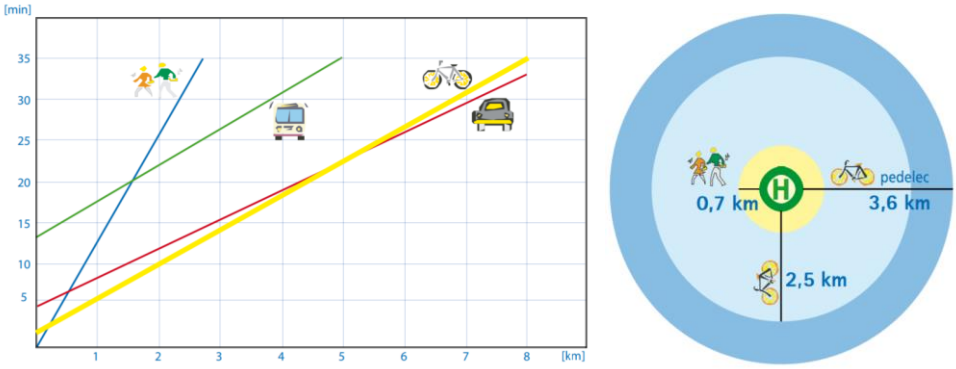


Figure 3: Compared to other transport modes cycling is the fastest option up to 5 km. Cycling attracts multimodal journeys as it could enlarge the catchment area of public transport stops dramatically. (Source of illustrations: 20 good reasons for cycling[18] (64))

Despite all the mentioned benefits some researchers and professionals found that people used bicycles because they had found it relaxing and they had simply enjoyed cycling more than other transport options (see figure below). According to Dutch reports, those commuters who walk and cycle regularly enjoy their journey more than others who use other modes. (65) (66) (8)

[18] http://bicy.it/docs/86/Trendy_cycling_EN_web.pdf (Cited: May 15, 2018)

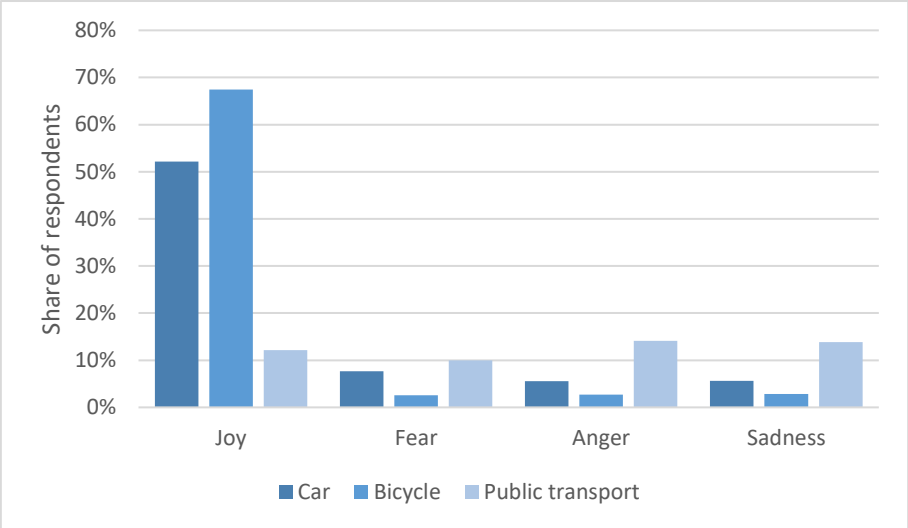


Figure 4: Emotions linked with various modes of transport in the Netherlands (Source of chart: Cycling in the Netherlands[19] (65))

Bike-sharing systems provide the flexibility to use a bicycle whenever it is the most convenient to get from A to B, without the necessity to own or have a bicycle at hand (e.g. if commuting or travelling). Bike-sharing, just like it was mentioned above about cycling, fills the gap of shorter distances when walking is too tiring, and it does not make sense to use public transport either. By facilitating on-way travels, bike-sharing has opened new opportunities which otherwise would not be possible.

Bike-sharing has various environmental, social, economic and transport-related benefits as bike-sharing increases cycling modal share and provides an additional, sustainable mobility option. The table below sums up the benefits of bike-sharing systems.

Transport and urban development related benefits due to increased cycling modal share and more flexibility by increased mobility-options	• Makes cycling more visible, promote cycling • Promotes sustainable, efficient and safe mobility • Influences travel patterns and user behavior • Reduces car use and car ownership • Reduces public space occupation of the number of private cars • Improves cycling and traffic safety • Encourages cycling infrastructure development • Avoids traffic congestions • Manages (public) transport demand and increases public transport use • Encourages multimodal trips • Provides a convenient last mile option
Environmental benefits due to higher share of zero-emission mobility	• Reduces air and noise pollution • Reduces CO_2-emissions • Contributes to climate change mitigation • Greater environmental awareness

[19] http://www.fietsberaad.nl/library/repository/bestanden/CyclingintheNetherlands2009.pdf (Cited: May 16, 2018)

Economic benefits due to various direct and indirect factors	• Positive city image • New employment opportunities • Extra revenues from advertising • Increases attractiveness for tourist • Savings with reduction of car infrastructure • Indirect economic effects of urban development and increasing livability • Cost savings from modal shifts • Lower implementation and operating costs (in contrast to other transport services) • Reduces fuel use • Individual financial savings
Social benefits due to increasing mobility options and social equity, better, more livable urban environment	• Increases the livability of streets and urban landscape (decreases spatial occupation) • More space for walking and cycling • Reduces the negative effects of motorized traffic (air pollution, noise etc.) • Increases physical activity and health benefits • Improves accessibility • Contributes to social equity by providing mobility options for those who otherwise would have limited access to public transport • Safer streets and urban environment for all

Table 3: Benefits of bike-sharing systems
(based on the sources of the literature review in chapter No. 2.1 and (67) (44) (46))

4 Bike-sharing systems – overview

In this chapter I introduce the concept of bike-sharing systems through their evolution. I give a short overview of the history of bike-sharing services regarding their technological aspects and spread. Later the chapter discusses the main benefits and the key determinants of successful bike-sharing systems. The discussed research question is as follows.

RQ-2	*Which are the main determinant factors of a successful bike-sharing system?*

Several definitions and terms exist for bike-sharing. The most commonly used terms are bike-share or bike-sharing (US and Australia related literature), cycle hire (UK) and public bicycle (China). Public bicycle share system (PBSS), public-use bicycles (PUBs), public bicycle system or scheme are also widespread. (56)
There is no common, clear and specific definition for bike-sharing as the technology and solutions vary considerably. These are the main characteristics of bike-sharing services defined by the OBIS handbook: *"A self-service, short-term, one-way-capable bike rental offer in public spaces, for several target groups, with network characteristics."* (44)
Bike-sharing programs offer bikes, which can be picked up and dropped off at self-serving docking stations. However, dockless bikes that do not require docking stations are part of today's rapidly evolving markets as well as e-bikes and greater public transport integration (See chapter No. 4.1 and No. 0 for more details). (15)

The idea of bike-sharing is simple. It provides the possibility to use a bicycle whenever it is a convenient way to reach the destination without any further commitment like bike ownership. Mostly one-way trips are done with shared bikes, which are typically short, less than 30 minutes long. (15) Generally, the systems are accessible with smart cards, PIN codes or smartphone applications, requiring the purchase of short-term tickets or long-term passes. Most systems operate 24/7 throughout the year, while others close or operate with reduced capacity if the weather or other conditions are less favorable for cycling (e.g. winter or
out-of-season period). There are schemes which are limited to a smaller site like a university campus, or to a specific user group such as commuters of a company. A marginal type of bike-sharing systems is the peer-to-peer[20] type which relies on the exchange of bikes. (68)

Bike-sharing is a good transport alternative providing an optimal mobility option when the destination is too far to walk and too close to use public transport or private cars. It can also fill the gap between homes or destinations and public transport stops as the first and last element of intermodal journeys. (20)

To sum up, the main characteristics of bike-sharing services are as follows:

- It complements public transport services
- Suitable for one-way, short trips and multimodal trips
- Provides easy access for all as the bikes are accessible on public spaces
- Self-service
- Low usage fees (in general free rides up to 30 mins)

[20] For example, the members of a community share their bicycles with others in an informal way, like the members of the cargo bike-sharing platform of Budapest do. https://kozteherbringa.hu/ (Cited: June 10, 2018)

4.1 Evolution of bike-sharing systems

Although the first bike-sharing launch dates back to 1965, before the 2000s the solution was not as popular as it is now. The first generations suffered from theft, vandalism as the bikes could be hired anonymously. After the technology evolved, as well as the role of cycling emerged among planners and decision makers, bike-sharing has earned its reputation. (69)

Researchers identify four generations of bike-sharing systems:

1st generation free-bike systems,
2nd generation coin-deposit systems,
3rd generation information technology based systems and
4th generation demand responsive multimodal systems. (56) (70)

1st generation free-bike systems

The first bike-sharing system was introduced on July 28th, 1965 in Amsterdam, Netherlands. Provo, a Dutch anarchist group introduced the program called White Bikes (*Witte Fietsen*). Ordinary bicycles were painted white and were provided for public to be the first free communal transport. The bikes were not locked, people could find them on the streets, they could use them and leave them for the next user whenever they wanted. The system collapsed within a few days as the bike were stolen, thrown into canals and the rest were impounded by the police. (71)
Although the launch of the first system was not successful, some small cities adapted the concept with additional transport policy considerations. (56)

2nd generation coin-deposit systems

In 1991, the first second-generation bike-sharing system was introduced in Farsø and Grenå, Denmark. The first large-scale second generation system was launched in Copenhagen, Denmark called Bycyklen (City Bikes).
As the first generation of bike-sharing systems was unsuccessful due to vandalism and theft, the second generation tried to respond to these problems. The bicycles were constructed from durable materials (such as solid rubber tyres) and non-standard components, which were not compatible with ordinary bicycles.
The bikes of Bycycklen were designed with advertising plates. Users could pick up and return the bikes at stations, at specific locations throughout the city center with a coin deposit. Despite the innovations, the system still suffered from theft and vandalism as the bikes could be used anonymously and for a small amount of deposit. This problem induced the development of the next generation of bike-sharing systems, which included improved costumer tracking. (71)

3rd generation information technology based systems

As the second generation of bike-sharing systems was not yet successful, further development was needed. The first 3rd generation bike-sharing system was Bikeabout in 1996 at the campus of Portsmouth University in England. The first city where a 3rd generation program was introduced was Rennes, France (Vélo à la Carte) in 1998. Third generation systems were popular in Europe as well as outside Europe especially in the U.S. and in China. (56) (71)
Stations were operated by a computer kiosk which was the user interface for registration, hiring, information etc. Smart card technology and kiosks made user identification possible, which contributed to the increase of security and user responsibility. The nowadays usual fare scheme was introduced with these systems as well. Usage fees and deposits depended

on the type of registration (e.g. short or long term). In most cases the first 30 minutes of use was free as it was included in the registration fee.
To integrate bike-sharing systems into the urban transport network, docking stations were installed close to public transport stops and hubs to attract intermodal trips. Some cities introduced an integrated ticketing system such as common access card to public transport and bike-sharing, or special fares or discounts for those who used both systems.
These new features made third generation systems more successful than the previous ones as they provided a reliable, accessible and comfortable mobility option. (56)

4th generation demand responsive multimodal systems
Innovation has evolved, which made way for fourth generation demand responsive models. The first scheme of this generation was launched in Montreal, Canada in May 2009. (72) These systems were built on the previous third generation improving former weaknesses with available new technologies (e.g. IT and GPS tracking).
As bike-sharing systems have become popular and cities realized their benefits, the aim is to integrate bike-sharing systems into the urban transport network both in physical and administrative terms.
There is no widely accepted definition for fourth generation systems, therefore I present these schemes by their main characteristics: (56) (70) (72)

- Distinct bicycles (color, special design or advertisements).
- Increased system flexibility such as modular structure, flexible docking stations or no stations at all (mobile technology led smart locks). Modular, mobile technology opens the opportunity to relocate stations according to usage patterns and user demands. Solar powered stations do not need to be connected to the energy grids, which provides great flexibility and easy implementation.
- State-of-the-art stations with touchscreen kiosks and solar panels provide easy access and further possibilities, such as registration or information services.
- Improved distribution of bicycles with specially designed vehicles for bicycle relocation. Continuously improved redistribution methods (e.g., automated technologies that facilitate demand-responsive bike relocation). Incentivized user-based redistribution (e.g. demand-based pricing scheme and price reduction in case the user leaves the bike at empty stations).
- Enhanced physical and informational integration with other transportation modes such as smart card integration with public transport operators or other service providers like car sharing operators.
- Developed pedaling technology such as electric-hybrid bikes (e-bikes or pedelecs). E-bikes target a larger scope of users and encourage cycling in case of less favorable topographical conditions.
- GPS or RFID tracking, which enhance bicycle security and deter vandalism and theft. By tracking the bikes, more information is available about user patterns, which provides plenty of possibilities for further analysis. Developing mobile applications based on real-time information is also possible.
- Increased use of crowdsourcing and participatory platforms.

The following table summarizes the four generations of bike-sharing systems and their characteristics.

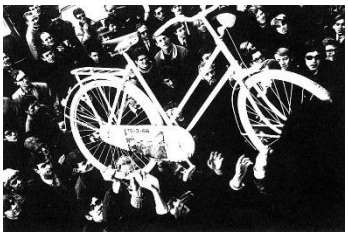
	**1st generation free-bike systems (1965):** • E.g.: White Bikes – Amsterdam, Netherlands • Regular bikes painted in a distinctive color • Unlocked bicycles located haphazardly throughout an area (no dedicated stations or kiosks) • Free access for all (anonym) • No redistribution • No usage fees
	**2nd generation coin-deposit systems (1991 / 1995)** • E.g.: Bycyklen – Copenhagen, Denmark • Custom bikes with special, durable components • Fix docking stations without kiosks (locked bikes) • Access with coin as a deposit (anonym) • Basic redistribution • No usage fees
	**3rd generation IT-based systems (1996 / 1998)** • E.g.: Vélos á la Carte, Rennes • Custom bikes with special, durable components • Properly located fix stations to enhance intermodal trips • Kiosks or user interface technology • Access with user card which requires registration and makes user identification possible • Advanced redistribution • Registration and usage fee (most cases the first 30 minutes for free)
	**4th generation demand responsive multimodal systems (2009)** • E.g.: MOL Bubi – Budapest, Hungary • Custom bikes with special, durable components • Properly located fix stations or station-less systems • Optimized distribution • Access with mobile technology and kiosks • Access to real time information (e.g. bike availability) • May include electric bicycles • Large scale integration • Registration and usage fee (most cases the first 30 minutes for free)

Table 4: The main characteristics of the four generations of bike-haring (based on (20) and (70)) (Sources of photos: vice.com[21], eglishtower.wordpress.com[22], theroadtosustainability.blogspot.com[23] and bkk.hu[24])

The start of the rapid expansion of bike-sharing dates back to 2005. In that year, JCDecaux, one of the biggest advertising companies launched Vélo'v in France, with 1500 bikes. Two years later, Paris launched Vélib' with 6000 bikes. Vélib' was the first large-scale bike-sharing system contributing significantly to the popularity of bike-sharing. In 2008, the first systems of the U.S. and China were launched. By 2010, there were operating

[21] https://www.vice.com/pt_br/article/jpekq7/os-provos-holandeses-inventaram-a-contracultura (Cited: May 14, 2018)
[22] https://englishtower.wordpress.com/2015/10/27/look-mum-no-hands/ (Cited: May 14, 2018)
[23] http://theroadtosustainability.blogspot.com.es/2011/09/short-history-of-bike-sharing.html (Cited: May 14, 2018)
[24] https://bkk.hu/2014/09/tobb-mint-5700-mol-bubi-felhasznalo-ujabb-rekord-szuletett-kedden/ (Cited: May 14, 2018)

bike-sharing schemes on all (inhabited) continents. In 2013, there were already 700 000 shared bikes worldwide and 2 years later their number hit 1 million. (73) As of June 2018, there are about 1600 bike-sharing systems and approx. 18 million shared bikes (both station-based and dockless) worldwide in almost 400 cities. (74)
Rapid expansion caused several system closures as well, especially in Spain and Italy due to inappropriate planning, lack of complex approach (bicycle-friendly street design, marketing, promotion etc.) and financial problems. (75) (76) (74) (44)
It can be concluded that over the last decade bike-sharing has become a standard tool to obtain sustainable transport systems in cities. Nowadays more than 1000 cities offer bike-sharing services worldwide to provide a flexible, convenient, eco-friendly and affordable mode to get from A to B. The popularity and rapid development of bike-sharing systems have been strengthened for several reasons, such as:

- Climate change and rapid urbanization related issues
- Growing role of sustainable urban mobility
- Spreading technology of mobility as a service solution
- Changing trends of ownership: sharing instead of having
- Developing communication and smart technologies, ICT applications (56)

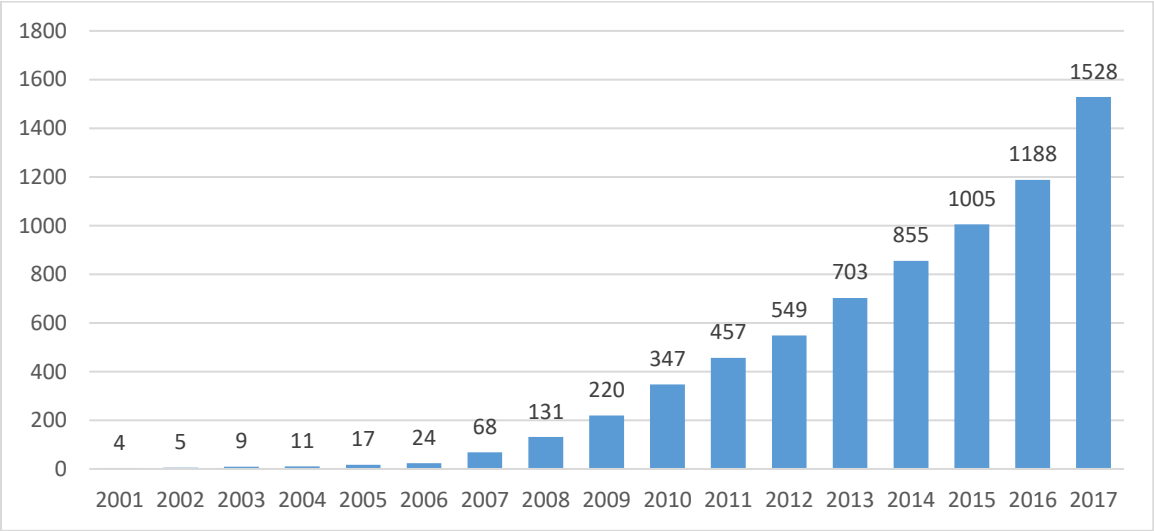


Figure 5: Number of cities with bike-sharing system worldwide since 2001[25]
(Source of data: The Bike-Sharing Blog[26] *and (56))*

Potential 5th generation dockless and smart bikes

Although the characteristics of fourth generation systems are not exactly defined, some articles state that dockless bike-sharing systems potentially fit into this generation. (15) However, it is also stated that dockless bikes represent a new generation as they rely on new technologies. (77) (78) In the era of big data, bike-sharing is becoming data-driven. New dockless bike-sharing operators brought not only a new technology but a new business model as their services lay on private funding. These systems have unique characteristics which may define a new, fifth generation of bike-sharing systems.

[25] Although a few bike-sharing systems existed before 2001, reliable data is not available about their exact number.
[26] http://bike-sharing.blogspot.com.es (Cited: May 14, 2018)

5th generation dockless and smart bikes (2014 / 2016):

- E.g.: ofo, Mobike, etc.
- Dockless bicycles without dedicated stations (there are some exceptions)
- All functions covered by the bicycle and the smartphone application
- Privately funded start-ups
- Access with smartphone
- Deposit and usage fee (pay per use)

Table 5: Fifth generation of bike-sharing services[27]

Since 2014, a new approach, dockless technology has emerged in the bike-sharing world. GPS-enabled bikes connected to smartphone applications offer users more flexibility as they can lock and leave the bikes wherever they want. Bicycles are equipped with a smart lock which can be opened and closed via a smartphone application. (Various system designs exist, see chapter No. 4.3 for more details.)
Dockless bike-share in its current, widely-known form, was introduced in China. Five students of the University of Beijing funded a startup called ofo[28] and introduced a bike-sharing scheme to serve the mobility needs within the campus. Early 2016, due to several external factors such as emerging shared mobility and popularity of smartphones, dockless bike-share began to spread in China.

As bike-sharing went dockless, the spread of the innovative technology and new business model have transformed the bike-sharing sector. The standard financial model of bike-sharing is based on public subsidize and government support. The whole dockless bike-sharing phenomenon is based on a different business model as it is funded by giant investors like Alibaba or Tencent. Moreover, as these systems function without public funding they do not depend on lengthy government procurement processes. As a result, private operators achieved unprecedented levels of growth.[29]
Mobike[30] and Ofo, two Chinese companies dominate the market. However, by 2017, US start-ups and Silicon Valley started to catch up on dockless bike-sharing. For example, LimeBike and Spin are two San Francisco-based start-ups that offer dockless bike-sharing services. After launching pedal bikes, both companies started to add e-scooters to their fleets. (79) Other market actors showed up in 2018. Uber bought Jump, an electric dockless bike-sharing service, and joined to the market race. (For more details about dockless bike-sharing market actors see chapter No. 5.2.) (80)
Although dockless bike-sharing is a hot topic in the media, researches and comprehensive studies about the systems, about their performance or exact numbers of the growth are not available. However, a bachelor thesis gives an overview about the worldwide dockless situation. (81) It is estimated that by June 2018 there are approx. 23 million dockless shared bikes in more than 250 cities worldwide.[31]

[27] (For more information see chapter No. 5)
[28] https://www.ofo.com (Cited: June 11, 2018)
[29] Reliable data about operation and usage is hardly available.
[30] https://mobike.com/global/ (Cited: June 11, 2018)
[31] According to ITDP-China Dockless Bike Share Map, http://www.itdp-china.org/dbs/index_en/#/getcompany/2 (Cited: June 11, 2018)

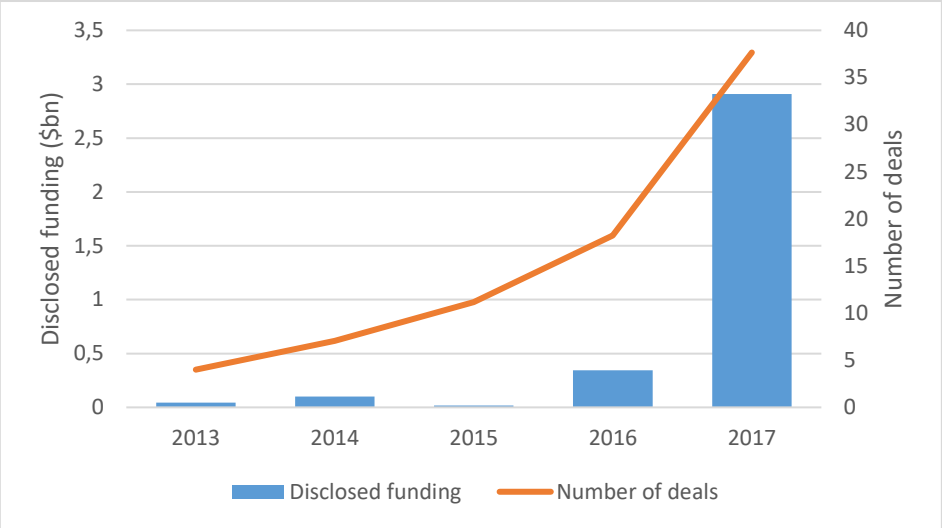


Figure 6: Investment in bike-sharing start-ups (Source of data: Financial Times[32] (82))

Although dockless bike-sharing provides new opportunities and flexibility, the technology and the unregulated business model and market entry have several drawbacks as well. Oversupply and unregulated use of public spaces caused parking problems, theft, vandalism and other negative effects related to quality management, rebalancing and maintenance. (83) (84) As cities realized these problems, they started to act and establish special regulations. Meanwhile, cities and operators started to work together and under agreements to provide more efficient services.

Some professionals are skeptical about the new technology and rapid market expansion, it is disputed whether dockless bike-sharing and the multi-operator model is the future. On the contrary, there are statements about proper regulations and approaches from cities' and operators' sides suggesting that dockless bike-sharing could be the future. (For more details see chapter No. 5.5)

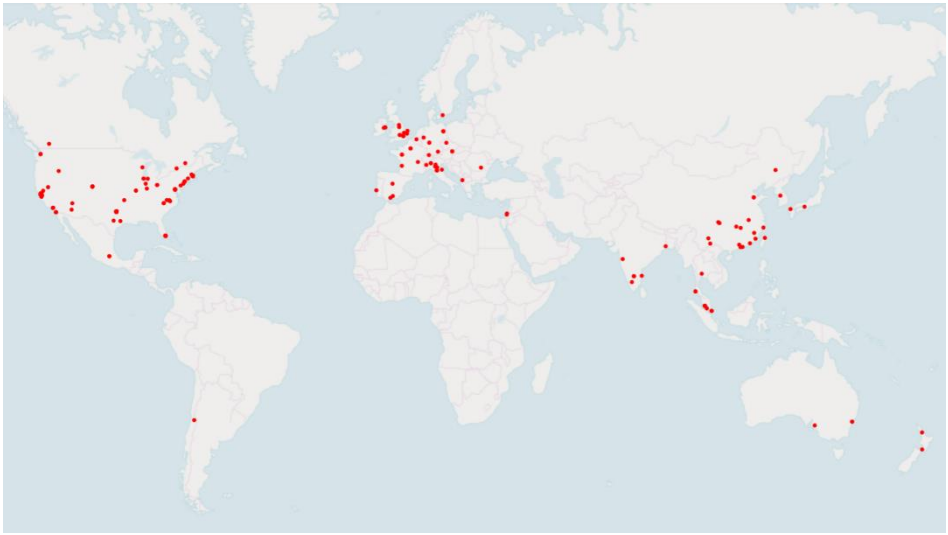


Figure 7: Dockless bike-sharing systems around the world in June 2018 (Data source: The Bike-Sharing World Map[33])

[32] https://www.ft.com/content/d6484c6a-398e-11e8-8eee-e06bde01c544 (Cited: June 11, 2018)
[33] http://www.metrobike.net/the-bike-sharing-world-map/ (Cited: June 15, 2018)

Chinese companies and technology has conquered the world markets, but it is worth to mention that dockless bikes had existed in other forms in Europe before. Actually, station-based and dockless technology both started around 2000. For example, Call a Bike[34], a dockless bike-sharing system operated by *Deutsche Bahn,* a German railway company, was put into operation in 2000. The aim was to provide first and last mile mobility option for those who commuted by train. At the beginning, users were required to call a certain telephone number to get the opening code for the bikes. Since then, the system has been modernized, and a smartphone application was introduced.
OV-fiets[35] (OV-bikes) in the Netherlands was introduced even earlier, in 2003. However, *OV-fiets* follows a slightly different operating model as the bikes are generally rented for 24 hours and not all renting stations are automated.
Besides that, the first smart locks for bike-sharing were developed in the early 2010s.

Case study – The history of bike-sharing systems in China

As China has the largest bike-sharing systems and the largest fleet in total as well. I decided to summarize the evolution and history of Chinese bike-sharing services in a short case study.

Before the 1990s - 2000s, bicycle was the most common transport alternative for Chinese people as well as it was a symbol of identity and sign of family status. In the 1980s the average number of bikes per person reached one. (85) However, with the rapid motorization which began in the late 1980s, cycling and the number of bicycles has decreased precipitously for various reasons. Complex socio-economic changes, growth of well-being and car ownership as the emerging symbol of social status, rapid road infrastructure development and urbanization without proper cycling conditions in Chinese metropolises, and many other factors contributed the decrease of cycling.
In China, a country that was used to be called "The country of bicycles" and where there were only 1.8 million private cars in 1985, the number of cars reached 60 million in 2008 and passed the 300 million mark in 2017. Meanwhile the number of bicycles significantly dropped, from 1995 to 2005, the country's bike fleet declined by 35%, from 670 million to 435 million, while the number of private cars more than doubled. Some cities started to blamed cyclists for the increasing number of crashes and congestions, bike lanes turned into car lanes and Shanghai even banned cycling from some downtown roads in 2004. (86) (87) (88) (89)

As air pollution and congestion dramatically increased an efficient response was required. In 2008, Hangzhou introduced the first bike-sharing system in China, initially with 2800 bicycles. The system developed rapidly and soon became one of the largest worldwide, with more than 78 000 bikes. (73) At the end of 2014, when the first dockless bike-sharing system was launched at the University in Beijing, there were already 750 500 station-based shared bikes, in 235 Chinese cities, which was almost 80% of the world's total fleet (946 000). (15)
In June 2015, ofo operated 2000 bikes within the campus of University of Beijing. By 2016, dockless bike-sharing attracted the attention of investors. With the growing popularity of shared mobility and mobile technology combined with giant investors, dockless bike-sharing boom hit the Chinese market and the number of dockless bikes has started to sharply increase. In April 2017, there were already 45 operators with as many as 7.2 million bikes. By October 2017, approximately 16 million dockless shared bikes were operated in China by more than 70 companies, while 14 million of these bikes were operated by Mobike

[34] https://www.callabike-interaktiv.de (Cited: June 11, 2018)
[35] https://www.ns.nl/en/door-to-door/ov-fiets (Cited: June 11, 2018)

and ofo. One third of the country's total fleet was operated in just three cities: Beijing (2.4 million), Shanghai (1.5 million) and Chengdu (1.2 million). The bicycles of the two mentioned operators were used for an average of 60 million trips a day in 165 cities.

These huge numbers of bikes have posed new challenges for cities: lack of cycling infrastructure and safety concerns on one side, oversupply, blocked public spaces and sidewalks and vandalism on the other side.
Dockless bike-sharing has operated in China since 2014, but it was largely unregulated during its infancy. In April 2017, Chinese cities, inundated with millions of dockless bikes and the challenges that came with them, began exploring options for regulating supply, managing public space, and ensuring user safety and privacy. As cities realized these problems, the Chinese government and cities established regulations for bike-sharing operators. Professional organizations like ITDP China[36] started to set up recommendations how to treat the dockless bike-sharing phenomenon. (84) (90) (91)
Several researches state that the number of short distance travels by car significantly reduced in Beijing and in Shanghai because of the emerging use of dockless bikes. Mobike Global estimates that the share of trips made by bicycle has more than doubled in Shanghai from 5.5% to 11.6%, and most of them are linked to public transport stops. However, China still suffers from the negative effects of its massive motorized traffic. (90) (85)

4.2 Key determinants of a successful bike-sharing system

The planning guidelines which were introduced in chapter No. 2.4 summarize the main factors and principals for a successful bike-sharing system.

Shared Mobility Principles for Livable Cities[37] consortium works to promote shared mobility. As the organization states, technology-driven innovation in shared transportation services are filled with opportunities. They set up principles to guide urban decision makers and stakeholders toward the best outcomes of shared mobility for all. Principles which apply to bike-sharing schemes:

- Comprehensive, complex and holistic city and mobility planning
- Prioritize people over vehicles
- Support the shared and efficient use of vehicles, lanes, curbs, and land
- Engage with stakeholders
- Promote equity
- Lead the transition towards a zero-emission future and renewable energy
- Support fair user fees across all modes
- Aim for public benefits via open data
- Work towards integration and seamless connectivity (92)

The main influence factors on bike-sharing systems can be divided into endogenous and exogenous factors. Endogenous factors can be adjusted to the exogenously given conditions such as institutional and physical design of the bike-sharing system. Exogenous factors are formed by the context of the city where the bike-sharing system is placed, and it is not easy to change them. Appropriate physical and institutional design are essential for a successful bike-sharing system. The tables on the next page explain the influencing factors better. (44)

[36] http://www.itdp-china.org/ (Cited: June 11, 2018)
[37] https://www.sharedmobilityprinciples.org/ (Cited: June 12, 2018)

Exogenous factors
City size
Climate
Mobility behavior (modal share)
Population density
Safety, security
Demographic factors
Economic factors
Geographic factors and topology
Existing infrastructure
Financial situation
Political situation

Table 6: Influencing endogenous factors on bike-sharing systems (Adapted from: OBIS handbook (44))

Endogenous factors			
Physical Design: Hardware & Technology	**Physical Design:** Service Design		**Institutional Design:** Operation & Financing
Access Technology (Smart Card, RFID, NFC, Smartphone, Code-based, Person in charge, Key)	**Size and density** (Number of bikes, station and slots, Station density, Size of the service area)	**Availability** (24 hours or limited, seasonal)	**Operators** (Advertising companies, street furniture providers, Transport companies, Bike-sharing business, Municipalities, Associations)
Bikes (Robust, Unique design, One size for all, Advertising space)	**Registration** (Short and long-time subscription)	**Charges** (Included free minutes and charged usage)	**Contracts** (Responsibility, Minimum service requirements)
Stations (Low-tech, High-tech, Advertising space, Dockless, Semi-dockless)	**Information** (Websites, Apps, Maps, Terminals)	**Public transport integration** (Information, Physical, Access & charges)	**Costs and Financing** **Operating costs** (Infrastructure & implementation, Running costs)
Software (Monitoring, Redistribution / maintenance, Billing, User processes)	**Target groups** (Defined group of users or accessible services to anyone)		**Operational financing sources** (Charges, Advertisement) **Sources for Subsidies** (Direct subsidies, Advertisement, Sponsorships, Parking enforcement, congestion charges)

Table 7: Influencing exogenous factors on bike-sharing systems (Based on: OBIS handbook (44))

Some of the factors mentioned above have greater influence on user behavior, operation and system success than others. The most important aspects and challenges in details are as follows: (44) (49) (45) (93)

- **Attractive and safe cycling infrastructure**
  Proper conditions, such as extensive and safe cycling network which encourages cycling, are essential, especially to attract new users who have not cycled regularly or at all before. High level of general traffic safety is essential. Unsafe cycling

conditions discourage cycling and it is one of the main reasons of system failure.[38] Urban planning and compact cities are also key determinants as they provide favorable, short distances for cycling. (65) However, strict cycling laws, such as compulsory helmet use, could decrease the attractiveness of the system. Education and information on the topic of traffic safety are useful too.

- **User accessibility**
  The system should be easily accessible regarding registration, finding a docking station or a bike, hiring and customer service. It is recommended to install 10–16 stations per km^2 and the stations or bikes shall be not more than 300 m apart (200-250 m ideally). Information should be easily accessible and the more ways for payment and hiring are available, the more accessible the bike-sharing system is.
- **Attractive fares**
  Fair and affordable charges and flexible membership options should be provided to attract users and increase social equity. Common fare structures should be implemented as well which make intermodal journeys more reliable.
- **Redistribution**
  It is closely linked to accessibility, but it is as important that it is worth to be mentioned in a separate point. User satisfaction can be achieved if the system is reliable and bikes are there if the users want to use them (or there are empty slots at the docking station to drop off the bikes). Various optimization methods are available about how to rebalance bike-sharing systems, while operators could establish special incentives to influence travel patterns and system balance. (For further information about rebalancing see chapter No. 2.2)
- **Good marketing, benchmarking**
  Promoting cycling, active mobility and the use of bike-sharing plays a great role as they make people interested, change behavior and overcome other barriers. Various good practices exist for promoting cycling and bike-sharing.[39] (65)
- **Bike and station design**
  The physical design should be vandalism and theft resistant, while the bikes should be suitable and convenient for all potential users. Some systems offer their customers special bikes such as cargo bikes[40] and tandems, while electric assisted bikes are getting popular as they provide more accessible services for elderly people. (56) (For more details about station design see chapter No. 4.3.1)
- **Financial model (ownership and operation)**
  Obviously, proper financial model is crucial for the long-term sustainability of the bike-sharing system. The model should ensure that all the implementation and operating costs are covered. (For more details about financial and business model see chapter No. 4.3.3)
- **Integration with other modes of transport**
  As it was earlier discussed, bike-sharing and cycling is more efficient on longer distances if they are combined with public transport. To enhance multimodal trips,

[38] Although this thesis does not focus on proper cycling infrastructure and on its importance, it is a key driver to make cycling attractive and it has an extensive literature as the topic is discussed broadly. For instance, the Hungarian Cyclists' Club has a collection of guidelines which is available here (in Hungarian): http://kerekparosklub.hu/szakmanak/kozlekedes/tervezesi-ajanlasok (Cited: June 12, 2018)

[39] For instance, Mobile 2020 Handbook provides plenty of good examples. http://mobile2020.eu/fileadmin/Handbook/M2020_Handbook_EN.pdf (Cited: June 12, 2018)

[40] For example, SeestadtFLOTTE in Aspern, Vienna: https://www.aspern-seestadt.at/lebenswelt/mobilitaet/mit_dem_rad (Cited: June 10, 2018) http://eclf.bike/presentations17/C1%20Lukas%20Lang%20170320_ECLC_SeestadtFLOTTE_LANG.pdf (June 10, 2018)

both physical (e.g. station or bike placement and rebalancing) and administrative integration (e.g. common fare structure and passenger information service) are needed.

- **Information challenges**
  More and more data is available about usage and cycling patterns, which opens new challenges for data analysts and provides new possibilities for research, system optimization, urban and transport planning, route planning, marketing and further applications.
- **Conceptual and management challenges**
  As it was discussed, bike-sharing depends on various internal and external factors. Therefore, managing them requires a complex approach from the beginning (feasibility studies, planning, operation, follow-up and evaluation, integration with public transport). The systems should be flexible and should be developed and adapted to real user needs.
- **Social challenges**
  Properly planned bike-sharing systems could address social equity problems by providing mobility options for underprivileged people. However, there are examples for systems which do not act on social problems. For more details about social challenges see chapter No. 2.6.

4.3 System types and business models

Considering the purpose of my thesis, there are two main aspects of system design, which should be discussed here. In this chapter I give an overview about existing station designs and deployment types. At the end of this chapter financial and business models are also discussed.
As market and technology develop quickly, I focused on identifying only the main types of systems. However, there could be some existing solutions which are not covered by the proposed classification. (The classification is based on (94) and (95))

4.3.1 Station design

Pragmatically, there are two main design methods: docked (or station-based) and dockless. However, there are schemes which have hubs at railways stations with operating staff who give and take back the bikes from users. Moreover, there are bike share lockers and even peer-to-peer bike-sharing exists. (94)

Station-based or docked (also known as fixed)

There are (usually on-street) docking stations to secure the bikes at specific locations. The stations are placed around key locations and in most cases they come with a terminal which makes registration and hiring possible. The bikes are attached to the stations with a special mechanism (slot). There are several solutions for the slot's mechanism, but the main concept is the same (see the figures below). In some cases, the bikes do not have an extra lock and they cannot be left elsewhere but at the stations. In other cases, to make temporarily locking possible, bikes come with an extra lock (e.g. providing the possibility to go to a shop without returning the bike).

Figure 8: Examples for docking mechanisms
Top left: bicielx, Elche, Top right: Rentbike Hotel by MOVUS, Valencia
Bottom left: Ecobici, Buenos Aires (Source: ITDP - The bikeshare planning guide[41])
Bottom right: MOL Bubi, Budapest (Source: BKK[42])

Dockless (also known as station-less or flexible)**:**

In the case of dockless technology bikes operate without heavy, physical stations. A secure locking mechanism is attached to the bike, normally it locks the rear wheel to block it. Usually the lock can be controlled with a smartphone app, but it can work other ways as well (e.g. users required to call the operator to get the code). In large-scale systems smart, GPS-tracked bikes are used.

Figure 9: Obike's dockless bike and its smart lock in Vienna

[41] ITDP - The bikeshare planning guide, page No. 73. (references: Aimee Gauthier), https://www.itdp.org/wp-content/uploads/2014/07/ITDP_Bike_Share_Planning_Guide.pdf (Cited: May 30, 2018)
[42] https://bkk.hu/2014/02/eloszor-probalhatjak-ki-a-mol-bubi-kozbringat-a-hetvegi-bringaexpon/ (Cited: May 30, 2018)

There are two main types of dockless bike-sharing systems:

- **Dockless** (also known as station-less):
  Within the geo-fenced service area, the users can leave the bikes wherever they want to leave them (following the local regulations like not blocking the pavements).
- **Semi-dockless** (also known as hub-centric or lock-to):
  It is a kind of hybrid system of dockless and station-based systems with smart bikes. Within the service area there are geo-fenced virtual stations (even marked parking areas) where the bikes should be parked. The station could be designated only for dockless bikes or can be shared with other bikes too. In some cases, these stations are marked with painting and signs (e.g. Urbo[43]). Regular bike stands could be used as well, in this case the bikes are equipped with bike locks and the users should lock the bikes to the stand (lock-to technology, e.g. Donkey Republic[44]). The bikes are GPS-tracked, relying on a built-in tracker or the system using the GPS module of the user's smartphone.
  The semi dockless model is expanding because it could eliminate the parking problems related to recently emerging dockless bikes.

Figure 10: Designated area for semi-dockless bike-sharing in London marked with painting and signpost (Sources: Paul Gasson – Twitter[45]; urbosolutions.com[46])

Figure 11: Parking areas for semi-dockless bicycles
Left - Semi-dockless Donkey Republic bike in a regular bike parking (Barcelona)
Middle – Dockless bike parking area in the U.S. (Source: Michal Naka - Twitter)
Right – Parking area for dockless bikes and scooters in the U.S. (Source: Michal Naka - Twitter[47])

[43] http://urbosolutions.com/ (Cited: May 30, 2018)
[44] https://www.donkey.bike (Cited: May 30, 2018)
[45] https://twitter.com/analogpuss/status/925678009348165633/photo/1 (Cited: April 15, 2018)
[46] http://urbosolutions.com/wp-content/uploads/2017/11/1-7-600x400.jpg (Cited: April 15, 2018)
[47] https://twitter.com/michalnaka/status/997904978172895232 (Cited: May 30, 2018)

Figure 12: Designated parking places for motorcycles in Madrid.
If it can work with motorcycles, it will work with bicycles as well.

4.3.2 Deployment types

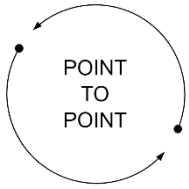
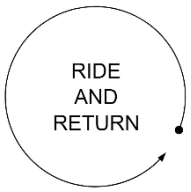
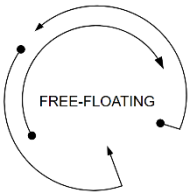
	**Point to point (A to B trips)** This type exists with docked and semi-dockless technology as well. Point to point systems allow users to pick up the bikes from a station and leave them at another one (or at the same). This type is the most frequently used one in cities. This solution provides flexibility to users to make one-way trips by bike-sharing.
	**Ride and return (A to A round trips)** This type exists with docked and semi-dockless technology as well. Ride and return systems require the users to return the bikes to the same station where they picked them up. This deployment is common where most of the trips are round trips, in most cases used for touristic purposes.
	**Free-floating (A to B without specific stations)** This type can operate only with dockless technology. Free-floating, dockless systems do not use dedicated stations. The bikes can be left anywhere within a specified area, and this provides great flexibility for users to lock the bikes as close as possible to their destination.

Table 8: Deployment types of bike-sharing systems

Possible combinations: operating models

The table on the next page gives more explanation and examples about existing operating models. It is important to mention that semi-dockless bikes should be left in the designated parking areas. In most cases, the operators promote right parking behavior with special incentives to avoid haphazard parking. However, users can leave the bikes out of the parking zones for dockless bikes which is penalized in various ways by the operators.

Station design / Deployment	Station-based, docked	Semi-dockless	Dockless
Point to point	Most traditional, 4th generation bike-sharing systems' operating model. Optimal solution for one-way trips, while the bikes are parked orderly at the docking stations. E.g. MOL Bubi or Valenbisi	More and more common model to avoid parking problems of dockless bikes. A cheaper and easier to implement alternative for station-based systems. E.g. Urbo	-
Ride and return	The bikes can be picked up at a specific location and they should be returned to the same place. Ideal for longer, return trips. In most cases the stations are placed around touristic sights, hotels or campuses. E.g. Rentbike Hotel by MOVUS	Like the docked type, but it does not require heavy, expensive docking infrastructure. E.g. Donkey Republic	-
Free-floating	-	Penalized behavior as the bikes should be parked in the marked zones.	Most dockless bike-sharing systems follow this operating model. The bikes can be picked up and left freely within the service area (users should follow the local parking regulations). On the one hand it provides great flexibility as the users can leave the bikes close to their destinations. On the other hand, it has several drawbacks as the bikes are not attached to a fixed object. E.g. Ofo, Mobike in most cities

Table 9: Operating models with examples (Based on (95))

Besides the models discussed in the table above there is another possibility called hybrid system which is a combination of point to point docked or semi-dockless systems and free-floating semi-dockless or dockless system. Which means that hybrid systems have dedicated stations (they can be docking stations or semi-dockless hubs) and the bikes can be left out of the stations as well usually for a special price or this feature can be included in the general membership fee too (e.g. SocialBicycles). (For further information about hybrid systems see chapter No. 6.1)

Note on terminology

Although in the classification dockless and semi-dockless bikes are separated into two subcategories, for the sake of simplicity I call both dockless in the rest of my thesis, unless it is necessary to distinguish them.

4.3.3 Financial and business models

Over the past few years, as shared economy and shared mobility have emerged, new and different business models have appeared. There are several business models to implement and operate public bike-sharing regarding public and private involvement and ownership. The table below summarizes the existing models. (As the actual business models vary around the world on a wide scale, there could be some exceptions which do not fit into the proposed classification. The main aspect of the classification is to examine who is responsible and for what: who is the responsible body for planning, funding, sponsorship and who owns and operates the system.)
Most bike-sharing systems are accessible with membership fees and usage fees. In few cases bike-sharing systems are only accessible for a defined user groups (e.g. employees, students, residents) but in most cases the services are available for all.

Provider	Financial and business model	Examples
Public-private partnership, sponsorship based (PPP)	Significant financial support from a sponsor in exchange of advertising rights with additional financial support from the city. Usually requires a third-party operator.	MOL Bubi (Budapest, Hungary) Citi Bike (New York City, USA)
Advertising company / street furniture contract (special type of PPP)	Primary revenues from third-party advertisers and additional revenues from usage fees.	Business model of JCDecaux or Clear Channel International. Valenbisi (Valencia, Spain) Oslo City Bike (Oslo, Norway)
Publicly owned - local authority manages	Usually highly subsidized with low fees for users. Contracts with a provider who owns and operates the system.	Aarhus City Bikes (Aarhus, Denmark) Capital Bikeshare (Washington, D.C., USA)
Publicly owned - public transport operator manages	Usually highly subsidized with low fees for users. A public transport operator provides and operates the system to enhance public transport services.	OV Fiets (Dutch Railways, Netherlands) Velos Jaunes La Rochelle
For profit enterprise, business to consumer model	A private company provides a profitable PBSS and operates the system with minimal or no governmental involvement	Hamburg (NextBike, Germany) Ofo, Mobike, Obike and other startups in various cities around the world[48]
Nonprofit organization	Associations / charities which frequently rely on subsidies from local authorities, usage fees and donations.	BIXI (Montreal, Canada) Rekola (Czech Republic) Nice Ride (Minneapolis, USA)

Table 10: Basic financial models of bike-sharing schemes (based on (96), (97), (56) and (70))

[48] The relationship between the companies and cities varies.

Docked bike-sharing systems in most cases are operated in public and private partnership or business to consumer models. In most cases, operating costs and funding are covered by public money. The operating model of dockless bike-sharing systems differs from previous practices. Private companies own, plan, fund and operate the systems by their own.

Some potential revenue resources to cover investment and operating costs:

- Advertising funding from city street furniture, billboards, bikes, and bike-sharing stations
- Member and nonmember usage fees
- Government or municipal subsidies
- Public–private partnership funding or pure private funding
- Bank loans
- Local funding, crowdsourcing etc.

5 Dockless bike-sharing systems

Dockless bike-sharing technology is becoming a global phenomenon. This chapter summarizes its identified implications for cities. The first subchapter discusses the recent trends of shared mobility and market liberalization by giving an overview about the current situation. After introducing some dockless bike-sharing operators I collected the most common arguments against dockless systems. Later, the chapter examines the recommended and existing actions related to regulations. The final subchapter outlines the analysis of dockless technology. The discussed research questions are as follows.

RQ-3	*What are the main characteristics, advantages and disadvantages of new wave dockless bike-sharing systems?*
RQ-4	*How should cities treat the dockless bike-sharing boom and their rapid expansion? Would market liberalization be a feasible option for bike-sharing? What kind of regulations and operating models would be necessary for a successful, small-scale market liberalization on city level? What are the possible risks of inaction?*

5.1 Trends in shared mobility and liberalization of transport services

Smart technology and IT based shared mobility and bike-sharing is becoming more and more popular, new market actors are popping up and technology is developing rapidly. Introducing a new bike-sharing scheme or offering a shared mobility option has never been so easy.
The following figure shows the trend of trips realized by the on-demand transport sector. These services are increasing worldwide, while China dominates with a 68% market share.

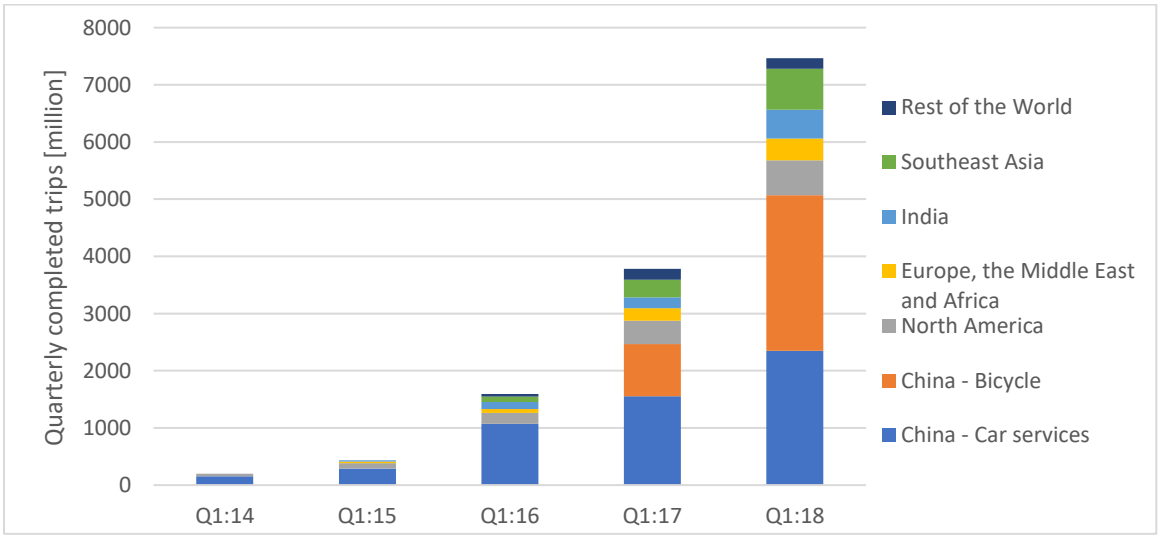


Figure13: On-demand transportation trip volume by region on global scale, including on-demand taxi, private for-hire vehicles as well as on-demand motorbike and bicycle trips booked through smartphone apps (Source: Hillhouse Capital, Kleiner Perkins (98))

As smartphone technology has become widely available, on-demand transport is increasing and new mobility options are arising. Shared mobility, such as ride-sharing[49] and vehicle-sharing[50] is developing while ride-sourcing platforms or on-demand transport

[49] Ride-share or carpool such as BlaBlaCar (https://www.blablacar.es/)
[50] Bike-sharing, car-sharing and other vehicle sharing options like motorbikes or schooters.

options like P2P or B2C[51] taxi services[52] or on-demand public transport[53] are also getting greater market share. (99) (100)
Vehicle-sharing is also developing. Besides car and bike-sharing services new types of vehicles are appearing. While dockless bike-sharing is becoming a global phenomenon and e-mobility conquers the world, shared e-scooters or e-rollers and motorbikes have hit the market in the US and recently in Europe and in other parts of the world as well. The possibilities are endless, new solutions are continuously arriving, autonomous vehicles being one of the greatest and most important examples. (101) (102)

Even if these new solutions have their drawbacks besides their advantages, the general trend is evident. Without going into the details, it can be concluded that more and more private companies (a lot of them have IT-related background) provide new and innovative mobility options which shape the mobility of the future. On one hand it is an advantageous trend as market competition enhances innovation and new solutions. On the other hand, the technological progress can be misleading, therefore it is important to mention that technology on its own does not solve the mobility problems of our cities.
A good example for that misunderstanding is e-mobility. Promoting e-vehicles instead of conventional ones might solve traffic noise nuisance or local air pollution but without additional traffic calming measures, e-vehicles still occupy a great amount of public space and generate congestions. Moreover, even the environmental impacts of e-mobility are contested because their footprint over the full life cycle depends on a lot of different factors related to the production of electricity and batteries. (103) (104)
Cities and mobility providers should work together. New technologies should be adapted while introducing additional measures and proper regulatory frameworks is crucial. Leaving enough room for innovation is important but long-term sustainability should be ensured at the same time.

Regulated market liberalization and multi-operator model in the case of transport services

There are many examples for market liberalization of transport services but in the bike-sharing sector it is a new phenomenon. The entry of giant dockless operators changes the way of the formerly common single operator model.

A good example for transport service market liberalization is the desired integrated European railway market – even if at first sight it is quite hard to compare with the bike-sharing sector as the railway market is a more complex area which requires more complex solutions. The official theory behind the idea of rail market liberalization is that greater competition will help create more efficient and customer-responsive railway services. Europe-wide open markets encourage greater competition within national markets. Rail freight transport and passenger services are liberalized, which means that any licensed EU rail company with the necessary safety certification can provide services throughout the EU. (105)
Even though the market of purely domestic rail passenger services is not yet being opened to EU-wide competition, this example and the idea behind the approach could help us to identify and understand the possible benefits of dockless bike-sharing operators.
To simply sum up the operating schemes for all cases, there are legal bodies who define the service requirements. These bodies are responsible for legislation, certification and enforcement of the defined rules and requirements. On the other end, there are companies who fulfill the requirements and compete for market share. And at the end, users and

[51] Peer to Peer and Business to Consumer
[52] Such as Uber (https://www.uber.com) or DiDi (https://www.didiglobal.com/)
[53] For example, demand responsive public transport services with small or even autonomous vehicles.

passengers can enjoy the benefits of regulated market competition such as comprehensive prices and high level of service.

There are several other examples for regulated multi-operator models and market liberalization in the transport sector which are as follows:[54]

- The operating model of the public transport buses of Budapest
  Since 2012, the bus fleet of Budapest is operated by a new approach. The Centre for Budapest Transport launched a call for tender for companies who could provide modern autobuses and appropriately qualified staff to serve the public transport network of Budapest. With those who fulfilled the stringent requirements of the tender and won, Budapest agreed on a long-term (8+2 years) public service contract. Opening the market for new actors created competition pressures and opened new opportunities for providing better services.
  Budapest and BKK are responsible for strategic planning, traffic management, passenger information and ticketing. BKK monitors the services and all operators have to do is operating the buses in accordance with the requirements provided by BKK. As a result, the average age of the buses dropped and the share of barrier-free vehicles dramatically increased. (106)
- Taxi regulations of Budapest
  In September 2013 new regulations were introduced for taxis in Budapest. The service providers must fulfill the requirements defined by BKK regarding fares, image, parameters of the vehicle and other standards. Only the licensed, certified companies can provide services. BKK also monitors the quality of the services and controls whether the taxis keep to the rules. Although these regulations are contested for several reasons, mainly because of the relatively high fixed prices and inflexible standards, the regulation serves as a significant example as it contains important lessons to learn. It is a negative and a positive example at the same time. (107) (108)
- Competition in the interurban bus industry
  The interurban bus network was liberalized in the UK in 1980, and in Sweden and Norway in the late 1990s. In 2013, after several legal actions, Germany fully liberalized its interurban bus services too. In 2014, Italy and in 2015 France opened their formerly regulated markets. And there are many other telling examples. (109) (110)

It can be concluded that the presented examples and their legal frameworks apply similar solutions. The follow an output-oriented and customer-centric approach which defines the required quality of service and the contract partners or operators fulfill these requirements.

5.2 Dockless bike-sharing operators

The following table summarizes some of the dockless bike-sharing operators and the main characteristics of their services. Dockless bike-sharing systems are getting more and more popular and new businesses and solutions are entering the market. I collected the most known actors, although there could be companies which are missing from the list.[55]

[54] I focus on the existing examples of Budapest because it is one of the cities of my case studies.
[55] ITDP China keeps records of dockless bike-sharing operators and cities' actions and regulations. http://www.itdp-china.org/dbs/index_en/#/getcompany/1 (Cited: June 16, 2018)

Name / Website	Founded	Operation	Bikes and users	Regulation / features	Comment
Mobike mobike.com	April 2015 China	200+ cities and 19 countries worldwide	200 million registered users and 9 million bikes	Score systems and reward scheme to enhance user responsibility	Mobike published a report about the performance and impact of their services on mobility situation and environment in China. (85)
Onzo onzo.co.nz	2017 New Zealand	Auckland New Zealand	DNA 10 000+ app. downloads	Bikes come with helmets due to mandatory helmet laws.	New Zealand's first and largest dockless bicycle sharing platform.
Ofo ofo.com	2014 China	250+ cities 22 countries	250 million users and 10 million bikes	User education and incentives for right behavior.	The world's first and largest (new wave) bicycle-sharing platform.
oBike o.bike	January 2017 Singapore	19 countries in Europe and Asia-Pacific	DNA 1 million+ app. downloads	Credit scoring system which rewards good behavior. The lower the user's credits, the higher the cost of a ride.	oBike started to manufacture and power assisted private bicycles.
GoBee gobee.bike	April 2017 Hong Kong	Asia and Europe	DNA 300 000+ app. downloads by November 2017	No special regulations.	Due to vandalism and theft, GoBee left the French market after 5 months of operation.
Limebike limebike.com	January 2017 Unites States	60+ cities in the U.S. and Europe, additional 20 campuses	DNA 10 000 bikes and 3 000 000 rides in total by May 2018	User education through on-line channels.	Offers electric scooters and both pedal powered and electric assisted bikes for cities, businesses, communities and campuses.
Spin spin.pm	July 2017 United States	18 cities and 30 campuses in the U.S.	30 000 vehicles (both scooters and bikes) and 1 million+ rides	Basic safety and parking information.	Offers electric scooters and pedal powered bicycles.
Donkey Republic donkey.bike	2015 Denmark	56 cities in 18 European countries and 2 cities in the US	2000 bikes and 20 000 users by May 2017. 50 000+ app. downloads by June 2018	Semi-dockless as the bikes should be locked to bike stands. Basic safety and parking information.	Basically, offers ride and return services with the possibility of on-way trips for additional fee.
JUMP jumpbikes.com	2010 United States	4 cities in the US, plans to enter the European market	DNA 10 000+ app. downloads	Electric assisted bikes. Basic safety instructions.	In April 2018 Uber, the shared mobility giant, acquired JUMP.
Social Bicycles socialbicycles.com	2010 Unites States	40 cities in the US and Europe	15 000 bikes and over 5 million rides.	Hybrid systems as it operates with light-weight stations equipped with bike stands and a terminal. However, the bikes can be left anywhere in the service area for an extra charge.	Social Bicycles is a service by JUMP with non-electric bicycles (also Uber owned).
Urbo urbosolutions.com	2017 Ireland	3 cities in the UK and Ireland	DNA 1000 + app. downloads	Policy framework ensures coordination. User Credit System. (free rides for good behavior, bans for bad behavior)	Semi-dockless bikes and marked parking areas.

Table 11: Basic information on dockless bike-sharing operators as of June 2018
(Data source: internet research, data shared by the operators via their official on-line channels)

As it was mentioned before, the list of operators above is not exhaustive and only includes some of the biggest actors. There are several other operators and new ones are popping up continuously. Here are some other operators and their websites:

- Hello Bike (Netherlands): hello-bike.net
- SG Bike (Singapore): sgbike.com.sg
- Bleeperbike (Ireland): bleeperbike.com
- Rekola (Czech Republic): www.rekola.cz

Most of the dockless bike-sharing operators above are newcomers in the bike-sharing sector or even in the mobility sector. These new actors mostly have IT backgrounds. Even though some of them offer ride-hailing or on-demand mobility services the great majority of them have experiences in e-commerce, social media, mobile or on-line payments. Dockless bike-sharing providers often backed by venture capital investors which make them independent from public subsidies to implement and operate their systems. (111)
However, there are operators which went bankrupt due to the financial bubble burst effect. Bluegogo's bankruptcy occurred in November 2017 causing 20 million users to lose their deposits. At the time Bluegogo was the third largest Chinese dockless bike-sharing operator. (84)

5.3 Arguments against dockless systems

There are several arguments against dockless technology which pop up in the media or at professional forums frequently, especially since it has become popular all around the world. In this chapter I collected some of these arguments and I tried to reflect on them including solution proposals.
Some arguments are only valid about rapidly spreading venture capitalist companies, because of low entry barriers like lack of regulations and formal agreements between operators and cities. Station-based systems in most cases are operated as a public service with official agreements and the revenues are complemented by public subsidies. Traditionally these systems were planned or even ordered by the cities themselves. As dockless bike-sharing systems do not need heavy infrastructure it provides a "lopehool" to operate the bikes without taking responsibility on them. When dockless bikes entered the European market, the problems were the same as in China, but on a smaller scale. As operators faced with vandalism and other problems, companies started to act in cooperation with cities. (For further information see chapter No. 0) (91)

Haphazardly parked bikes flood cities, occupy street space and pavements

Last year news about the dockless bike-sharing boom of China and later in Europe and elsewhere hit the global media. Pictures about bikes flooding the streets and sidewalks of cities went viral. It is evident that oversupply, public space occupation and vandalism are big problems but we must remember that the coin has two sides.
First, bike use and bike-sharing systems contribute to the reduction of congestions and the number of journeys conducted by car. Dockless systems have the same effect. They contribute to the revitalization of street space occupied by car traffic and car parking. With proper regulations, oversupply would be avoided. Right user behavior could be encouraged with education[56] which could also help solving the problem of occupied pavements and urban spaces. Some companies already introduced a scoring system to fine

[56] LimeBike's video about right parking behavior is a good example for education measures. https://www.facebook.com/limebike/videos/2024199054522558/ (Cited: June 13, 2018)

bad behavior and reward compliant users. (112) If a user leaves the bicycle unlocked or parks it incorrectly the usage fee or the deposit rises.
Second, shared vehicles are not the main cause of public space occupation in cities. Instead, in most cases private cars occupy a great share of street space while shared vehicles reduce space occupation and cycling revitalizes street and urban life. (113) (114) (115)
In my opinion, this kind of media hype has great negative effects on public opinion about bike-sharing systems and sustainable urban mobility as this media behavior follows the old, bad, car-centric way of thinking. The real cause of the public space occupation problem is not else than private car. It is easy to spot cars which occupy street space, and which are left out of parking places or even where parking is prohibited. I think that bike-sharing and dockless technology should be promoted as a great possibility to solve our urban transport problems, rather than stigmatizing the technology and focusing mostly on its negative side – although the challenges should be undoubtedly handled.[57]
The pictures below show some meaningful examples. It is undeniable that street space occupation should be solved, but I state that properly regulated (dockless) bike-sharing is one of the effective solutions to address the problem rather than being the real source of it.

Figure 14: Not only bikes block sidewalks
Left - Jump bike locked to a pole with its lock (Source: CityLab[58])
Right - Social Bicycle operates as a hybrid system, the bikes can be locked to dedicated stations and to regular bicycle stands as well (Source: Social Bicycles[59])

Figure 15: In most cases bicycles are not the main reason of blocked sidewalks. The sad fact is that these vehicles occupy valuable public spaces legally. Sometimes we cannot see the wood for the trees and we do not blame the real source of the problem. (Source of the picture on the right: Jarokelo.hu[60])

[57] I do not state that positive media reactions do not exist. On the contrary, there are various articles about the opportunities of dockless bike-sharing systems and about regulations which can solve the negative effects.
[58] https://www.citylab.com/transportation/2018/01/what-people-mean-when-they-call-dockless-bike-share-a-nuisance/550253/ (Cited: June 13, 2018)
[59] https://help.socialbicycles.com/hc/en-us/articles/201135365-Is-Social-Bicycles-stationless- (Cited: June 13, 2018)
[60] https://jarokelo.hu/bejelentesek/budapest/27074/leparkolt-jarda (Cited: June 13, 2018)

Figure 16: Irony on haphazard parking which highlights the real problem: user behavior and not (only) the technology itself. "The problem with dockless cars is people just park them wherever they want. I think this pilot program has gone far enough and it's time for put a stop to it." (Source: Peter Krupa - Twitter[61])

Figure 17: Photos of abandoned bicycles went viral causing general outcry. Before making ill-considered decisions, we should think first. Which is worse of the examples above? We should consider the hidden possibilities of smart bikes and create proper legal and physical urban environment for successful operation.
Left – A worker collects abandoned smart bikes in China (Source: cbnc.com[62])
Middle – Car heap at a junkyard (Source: scrapcarsite.co.uk[63])
Right – Diesel car graveyard in California after Volkswagen emissions scandal[64] (Source: news.sky.com[65])

Smart bikes are GPS-enabled, which makes tracking possible. Therefore, bikes that are parked in the wrong place or left unlocked should be removed by the operators and user behavior should be regulated as well – as this solution already exists in case of most operators.
Moreover, a smart lock which enables parking and locking the bike in designated parking areas only could be a simple and easy solution too.

Theft, vandalism

It is undisputed that dockless bikes, especially those which do not require the users to lock the bikes to a fixed object, are more exposed to vandalism and theft than station-based bikes. Consequently, the phenomena of theft or vandalism may not be completely eradicated. In some cases vandalism can reach high levels. For example, Gobee.bike decided to leave the French market after thousands of its bikes have been stolen or

[61] https://twitter.com/peterkrupa/status/953731240913526785/photo/1?ref_src=twsrc%5Etfw&ref_url=https%3A%2F%2Fwww.citylab.com%2Ftransportation%2F2018%2F01%2Fwhat-people-mean-when-they-call-dockless-bike-share-a-nuisance%2F550253%2F (Cited: June 13, 2018)
[62] https://www.cnbc.com/2017/07/18/bike-sharing-boom-in-china-pedals-to-new-heights.html (Cited: May 21, 2018)
[63] http://www.scrapcarsite.co.uk/images/scrap-car-collectors-covenrty-west-midlands.jpg (Cited: May 21, 2018)
[64] More information here: https://en.wikipedia.org/wiki/Volkswagen_emissions_scandal (Cited: May 21, 2018)
[65] https://news.sky.com/story/vw-emissions-scandal-german-carmaker-storing-300000-diesels-in-graveyards-11308274 (Cited: May 21, 2018)

damaged. (91) However, proper deterrent regulation, GPS tracking, user identification and education could solve these problems.
Vandalism occurs regardless of station design. Even station-based systems are vandalized. For example, 12-19% of the bikes of Vélib' are stolen annually. (116) The best way to avoid vandalism is promoting bike-sharing and increasing its public acceptance. If bike-sharing is popular and people utilize it, vandalism rarely happens and people take care of the bikes.

Figure 18: Although dockless bikes are more exposed to vandalism, it happens with station-based bikes too
Left – Dockless bike dumped on the top of a bus stop shelter in Melbourne (Source: Daniel du Plooy - Twitter[66])
Right – Vandalized (station-based) Vélib' bike in Canal Saint-Martin, Paris (Source: Blog de Denis[67])

Problems related to maintenance or rebalancing

Redistribution and maintenance is needed for all kind of bike-sharing systems. There are several articles about dockless bikes in bad conditions or without sufficient rebalancing. These cases are mostly caused by low entry barriers and lack of agreement and regulatory framework. These problems could be avoided by proper agreement between operators and cities.

Commercial long-term sustainability is not clear and certain

The opinions about the issue of long-term commercial sustainability are contradictory. There are sources which are more optimistic and there are others who say that the new business model is hardly sustainable.
There are a lot of arguments about the bike-sharing bubble and its soon to happen collapse. Rapid expansion of dockless systems happen as a result of huge investments by venture capitals to raise market share. The lossmaking prices cause collapse that spoils rivals and leaves monopoly for the strongest actor. (117)
The companies seem to be sure about becoming profitable on user revenues. Some analysts believe revenues will come from travel data by enabling marketing companies, real estate planners or local retailers. (118) (119)
"The commercial sustainability of dockless bike-sharing systems is not so easy to figure out" – said Mr. Niccolò Panozzo, development officer of ECF in an interview. (120)
The great amount of deposits could also be a driver as they cover costs and offer opportunities for other revenue-generating moves. (121)
To avoid liquidity and fundraising issues some smaller Chinese start-ups used deposits to pay expansions and fund operations. Hundreds of thousands of consumers have

[66] https://twitter.com/DanielRDuP/status/909597625405415425 (Cited: June 13, 2018)
[67] http://www.leblogdedenis.com/2016/01/08/que-trouve-t-on-au-fond-du-canal-saint-martin/ (Cited: June 13, 2018)

complained after bankrupt companies failed to return their deposits. After the problem occurred, China's transport ministry and the Chinese central bank jointly introduced a regulation to ensure this situation won't happen again. (122)
To ensure long-term financial sustainability, cities should set up proper regulations, including financial requirements and guarantees to provide reliable services.

Dockless technology is not the future, it is only about data

A big business opportunity could lie in targeted advertising based on travel data that are collected during each ride. Targeted advertisements or offers could be based on the users' everyday travel patterns where they are likely stop for a drink, shopping or to have dinner. Some companies also offer coupons and other inducements to boost customer loyalty. (123)
Data could be a good reason to invest into bike-sharing besides of rental income. Users generate location data that reveals patterns in consumer traffic, which can be valuable for a lot of market actors. However, some start-ups declared they do not sell data for third parties. Despite this, investors like Alibaba or Tencent may have access for travel data as they own bike-sharing companies and therefore do not count as "third parties". (124) Introducing a proper regulatory framework can prevent the misuse of personal data.
Another approach to this argument is that travel data is already available from other sources. Big data analytics is developing, social media activity, smartphone applications that track user movements provide a lot of information. There are several applications which are especially designed to track cycling movements and to provide data about cycling patterns. Dockless bikes could be much more expensive then these alternative data sources. However, it can be still a main driver for private companies.

Negative effects on local economy: bike rentals, repair shops and manufacturers

There are some arguments about bike-sharing systems having negative effects on local economy. It is argued that people start to use public bikes will not use private bikes anymore, which cause decline of revenues.
In most cases bike-sharing does not compete with private bikes because people use them for different purposes. Bike-sharing systems are used for shorter distances, usually as part of a mobility chain (e.g. "las mile problem") by people who do not use a private bike every day or when using a private bike is not a convenient option. Moreover, bike-sharing attracts new bicycle users who might buy and use a private bike in the long run. (76)
There are some examples which show that local businesses' or manufacturers' income dropped as bike-sharing became popular. (125) To avoid declines, cooperation between local businesses and bike-sharing operators should be established. Public bikes need repair just like private ones. Shared bikes can be produced locally relying on local bicycle production capacity to achieve economic sustainability.

Based on the examples above, it may be concluded that most of the problems occur because of the lack of agreements between the operators and cities and proper preparatory work. The following subchapter gives an overview about the necessary acts. The summary describes how cities can avoid the mentioned troubles, what kind of actions were implemented already and what professionals suggest.

5.4 Regulations

The shift from station-based bike-sharing to dockless solution brings new opportunities for cities to boost urban cycling. Dockless technology hides a lot of advantages, however it can result in several problems as well, mostly due to unregulated market conditions and lack of commitment between bike-sharing providers and cities.
In most cases bike-sharing systems are planned and operated in cooperation with the cities, or even the schemes are operated by the cities themselves. The dockless bike-sharing boom brought a new approach as private companies started to provide their services without sufficient preparatory works or cooperation with local authorities and experts. This is an undesirable approach which should be avoided due to the problems it generates. Therefore, some professional state that it is better to avoid the risk of inaction and cities should act proactively, they should work together with cities and introduce proper regulations.
Some key actors presented common position papers to urge cities to develop frameworks which ensure that dockless systems contribute to a successful urban mobility strategy. Others presented detailed guidelines about the optimization of dockless bike-sharing systems. Eventually, cities started to react to the dockless bike-sharing phenomenon.
To provide an overview about the actions of cities, professional organizations and policy makers I highlight some examples.

5.4.1 City action examples

Taking responsibility and regulating dockless bike-sharing is becoming an increasingly hot topic in a lot of cities worldwide. Media and citizens claim for the avoidance of nuisance and vandalism caused by unregulated dockless bikes, therefore legal actors, transport departments and city councils started to work on the topic. By April 2018 more than 30 cities worldwide have drafted or adapted dockless bikeshare regulations. (126) ITDP's dockless bike share on-line map[68] shows these cities.

When I started to work on my thesis one of the first aspects that I wanted to examine about dockless bikes was regulations. I wanted to find out what kind of regulations were necessary (if any at all) and which were the key topics that should have been addressed to avoid the negative effects of dockless bike-sharing systems.
Outcome oriented service agreements and strict contracts both have their own pros and cons. During my research[69] conducted about how cities treat the new dockless phenomenon I realized that similar problems occur worldwide but cities' reactions vary. There are examples for do nothing approach and strict regulations as well. Some cities even banned dockless bike-sharing operators. However, after a while, as valuable experiences have been gained, it seems that more and more cities decide to act progressively and cooperate with the operators and regulate the market.

[68] http://www.itdp-china.org/dbs/index_en/#/getcompany/1 (Cited: June 15, 2018)
[69] I searched for information on the websites of the cities and transport departments, operators and I used the findings of an already mentioned thesis. (81)

Cities' approaches can be divided to the following categories:[70]

- There are Chinese cities like Shanghai and Beijing which banned additional dockless bikes to avoid massive oversupply that had previously occurred. (84) I have not found any example where dockless bike-sharing operators were totally banned.
- There are cities where dockless bikes operate and a wait-and-see approach is followed, which means that these cities have not established any formalized regulations, agreements or have not done any other comprehensive actions supporting or against dockless bike-sharing operators:
    - Budapest (for further information see chapter No. 7.3.1)
- There are cities where dockless bike-sharing is temporarily banned until proper legal regulatory environment and a trial period will be established:
    - Amsterdam*
- There are cities which allow dockless bike-sharing services while started to establish special regulations:
    - Barcelona*
- There are cities which are open for dockless bike-sharing providers and have initiated a pilot program to see whether dockless bikes are suitable and what kind of regulations and additional interventions would be needed:
    - Auckland* (New Zealand)
    - Los Angeles (US) (127) (128)
    - Milan (Italy) (46) (129)
    - New York (US)*
    - Seattle* (US)
- There are cities which already implemented a kind of regulatory framework or requirements for dockless bike-sharing services or already concluded agreements with the operators (the covered and regulated topics are similar in most cases but the details vary widely):
    - Various Chinese cities (84) (90) (130)
    - Dublin (Ireland)
    - London* (UK)
    - Manchester (UK) (131) (84)
    - Sydney* (Australia)
    - Vienna (Austria)*

Another interesting aspect that there are cities which had already implemented a station-based bike-sharing before they allowed the operation of dockless bikes which could be complemented the existing services like it happened in Dublin, London or Barcelona. There are other cities where there were no bike-sharing services at all before the dockless operators arrived like in Auckland.
Besides giving a general overview, I collected some examples which provide more detailed information about cities' actions. These examples are as follows (in alphabetical order).

Amsterdam – Netherlands

In summer 2017, five dockless bike-sharing companies operated in Amsterdam when the city announced a temporary ban on them as many locals complained about dockless bikes occupying parking places for their private bikes. Some Amsterdamers stated that dockless bikes were only another example for the tourist industry excess as most of the locals had their own bikes and OV-Fiets served the needs when bike-sharing was needed. Meanwhile

[70] Cities marked with "*" are detailed on the following pages, others are not (for further info see the sources).

the city administration explained that dockless bikes might threaten bicycle use in the city as they took the space from private bikes and use it as a place of issuance. (132) (133)
The city of Amsterdam carried out a public consultation and the final policy is expected to be approved in the autumn of 2018. They will start a trial period with a possible extension of up to three years. Maximum three operators will be allowed in the city and the regular parking rules will apply to them. (134) (119)

Auckland – New Zealand

In December 2017, Auckland Council has issued a trial period until the end of February 2018 for Onzo[71], New Zealand's first dockless bike-sharing platform. Onzo and the city of Auckland developed a code of practice which defines the service requirements regarding safety and maintenance, operations, costumer experience and education, data sharing and integration with a piloting MaaS project. One interesting momentum in the regulations is that the dockless bikes should be parked next to regular parking facilities but without using the bike racks leaving them available for private bikes. (135) (136)
At the end of February, the test period was extended for an additional period of three months and the number of bicycles was almost doubled to provide more reliable services as the fleet proved to be too small. (137) Meanwhile Auckland Transport regarded the trial period successful and they abandoned their plans about establishing a bike-sharing system by public investment. They started to plan the system before the test period was initiated, before the dockless bike-sharing boom, when the possibilities were limited. But during the test period they realized that supporting a commercial operator's system would be more beneficial and economical for the city than establishing a scheme that required ratepayer funding. Moreover, the city plans to involve other operators in the future. (138)

Barcelona - Spain

The City Council of Barcelona addresses the problem in a complex way. Instead of focusing only on bike-sharing systems they decided to draft a regulatory framework for shared mobility, including all shared modes to regulate services and use of public space. The proposal will be finalized in 2018 to maximize the benefits of bike-sharing, car-sharing and scooter-sharing while reducing the experienced negative effects of them.
As the pre-study concludes, vehicle-sharing services help to achieve the city's sustainable goals but there are some drawbacks at the same time which should be discussed. Currently 15 companies are operating vehicle sharing services in Barcelona. (139) (140) (141)

Dublin – Ireland

On 30th May 2018, Dublin launched a regulated dockless bike-sharing scheme with two operators, Urbo and Bleeperbike, two Irish companies. Both systems are semi-dockless, which means the bikes should be locked to bicycle stands. To provide more parking spaces for bikes, the city of Dublin installed 1300 extra bike stands before they launched the new systems. The city expects that dockless bikes complement the services of Dulinbikes[72], the Irish capital's station-based bike-sharing system. (142)
The approved regulations, the result of an almost one year long period of preparatory work, clarify the desired operations. The first draft and public consultation was initiated in summer 2017, while information sessions were held for potential operators at the beginning of 2018. (143) (144) (145)

[71] http://www.onzo.co.nz/ (Cited: June 14, 2018)
[72] http://www.dublinbikes.ie/ (Cited: June 15, 2018)

London – UK

In September 2017, London established a code of practice for dockless bike-sharing. Transport for London (TfL) and the city of London state that dockless bikes have the potential to get more people on cycling. However, the system(s) must work without negative impacts on city life - this is why the regulations are necessary.
The document sets detailed criteria for operators and their services. First, the operators must engage with all relevant local authorities. Second, the requirements cover the topics of Safety and management, Operations, Customer experience and education, Data requirements, Environmental issues and Accesibility. (146)
As of June 2018, three dockless and one station-based bike-sharing system operate in London.[73]

New York – US

There are cities which see great potential in dockless technology, New York is one of them. In the end of 2017 Bill de Blasio, mayor of NYC announced a pilot to expand bike-sharing services with dockless technology. (147) According to the plans of the city they want to strengthen the existing bike-sharing system called Citi Bike, meanwhile they would like to prioritize new systems which complement the existing services.
In late July 2018 the dockless bike-sharing pilot provided by five operators will be launched in four boroughs. Each community will receive at least 200 bikes, including pedal-assist ones. NYC awaits for the conclusions regarding the performance of the shared bicycles in these neighborhoods which have not experienced bike-sharing services before. (148)

Seattle – US

In July 2017, Seattle launched a six-month pilot program to see the dockless bike-sharing systems' performance after the former bike-sharing program was discontinued in the same year. As the city states, they can harness the innovation and competition of private bike share companies. Market actors should obtain a permit to supply and operate the bikes, the requirements are available on the website of the Department of Transportation. It defines directives regarding safety, parking, operation, data sharing, usage fee related aspects as well as the application requirements and procedure. (149) (150)
The test period has proven to be successful, almost 75% of the citizens like dockless bikes. Two survey and ridership data have shown encouraging results. However, there were some problems with improperly parked bikes, but this is the role of the test phase and the city of Seattle works on the possible solutions. More findings and recommendations for the permit program will be presented in June 2018. (151) (152)

Sydney – Australia

In December 2017, Sydney Council devised the city's bikeshare guideline which set out the expectations for dockless bike-sharing operators. The city offers a transparent webpage providing information for users and future operators.[74] The guideline covers the following topics: Customer safety and conduct, Safe bike placement, Distribution and redistribution of bikes, Faulty, damaged or misplaced bikes, Legal and insurance, Data sharing, Council

[73]On the blog of Oliver O'Brien, researcher in digital cartography and data visualization, various articles are available about the possibilities and performance of dockless bike-sharing systems in London an in the UK. http://oobrien.com (Cited: June 14, 2018)
[74] As of June 2018, there are four dockless bike-sharing operators in Sydney.
http://www.cityofsydney.nsw.gov.au/explore/getting-around/cycling/dockless-bike-sharing
(Cited: June 14, 2018)

staff access to bikes, Fees, Collection and relocation of faulty or damaged bikes and Unused bikes.

Vienna – Austria

Dockless bike-sharing operators entered the streets of Vienna in August 2017. At first the city published some recommendations to enhance proper user behavior and bicycle parking. The bikes should be left next to bicycle parking facilities or in the car parking lane. Parking on the sidewalk is allowed only if the its wider than 2.5 meter and if it does not obstruct others. (These recommendations are valid for private bikes as well.) (153)
At the end of July 2018, after almost one year of experiences, the city introduced new regulations for dockless bikes. Vienna defined a cap for the number of dockless bicycles that can be operated. The city also decided that it will remove the haphazardly parked bicycles and in return it will fine the operators for EUR 700. (154)

5.4.2 Recommendations by professionals

Besides cities, organizations working around the world with cycling, transport or city development started to focus on dockless bike-sharing and its policy aspects as well. In this chapter, I will introduce the most important recommendations I found.

Institute for Transportation and Development Policy (ITDP) – Global organization

ITDP[75] works around the world to improve the quality of transport systems and to provide policy solutions which make cities more livable, sustainable and equitable. The organization has followed the dockless bike-sharing expansion first-hand as they work in China and have other offices worldwide. They have a dedicated page on their website for dockless bikes[76] and they organized a webinar on the topic (126). In May 2018 they published a recommendation and a periodic evaluation framework for cities about how to regulate and optimize dockless bike-sharing systems. (46)
ITDP states: "*Even though the city does not provide funds to directly support dockless bikeshare, its operation depends on the use of city-owned streets, sidewalks, and other public infrastructure.*"

According to ITDP, it is recommended for cities to establish a permit system on which the collaboration between the city and operator(s) could rely. It could be a request for proposals or memorandum for understanding or any other similar legal mechanism which should include the followings measures.

1. Integrating dockless bikeshare into existing mobility and accessibility goals
Bike-sharing as a sustainable mobility solution should fit into the city's transport and other (economic, health etc.) policies and vice versa. Bike-sharing should be defined as part of the future and the policy should be harmonized with the city's common development vision.

[75] https://www.itdp.org/ (Cited: May 22, 2018)
[76] http://www.itdp-china.org/dbs/index_en/#/getcompany/2 (Cited: May 21, 2018)

2. Establishing operations objectives for dockless bikeshare and adopting policies

Cities should address specific challenges of dockless bike-sharing. This topic is based on four pillars, each explained by various specific objectives.

1.1 Effectively manage public space

The aim is to avoid public space occupation of parked bikes. The most important issues are as follows.

- Fleet size cap:
  To avoid oversupply and to optimize the use of public space and bike availability, defining an optimum fleet size with a cap could be an effective measure. The number of operating bikes should be adjusted on performance and ridership data continuously.
- Time-bound response to parking complaints:
  Operators should be required to respond to parking problems or abandoned bicycles in a certain time frame (typically within two hours). If the operator does not solve the problem in time, the city has to have the right to fine the operator or remove the bike on the operator's expense.
- User education and information:
  Operators must provide easily accessible information about required user behavior which has to be agreed by every user before they start to use the system.
- Lock-to requirement / Dockless bike parking areas:
  Locking the bike to a fixed object (e.g. bike stand) can prevent parking problems and sidewalk occupation. If the city decides to establish this requirement, bike parking facilities should be improved as the demand for bike stands is expected to grow. In this case the city should define the required number and placement of bike stands and should work together on that issue with the operator(s). Cities could install marked parking areas for dockless bikes as well, which further enforces right parking behavior. (Previously defined as semi-dockless bike-sharing in chapter No. 4.3.).

1.2 Fostering equity and accessibility

It is important to provide accessible and reliable bike-sharing services for all, therefore at least the following issues should be considered.

- Bike distribution requirement:
  Cities should define minimum service level such as minimum and maximum or optimal number of bikes per defined zones (could be neighborhoods or other areas). This requirement could improve the reliability of the system and ensure more equitable spatial distribution of bikes across the city.
- Flexible and reduced payment methods:
  Accessibility of dockless bikes is limited as they require a smartphone and a credit card. Cities should require alternative payment options such account top up with cash at stores. To ensure that bike-sharing is affordable for all, special fares should be dedicated for lower-income social groups.
- Public transport integration:
  As (dockless shared) bicycles can complement and make public transport more accessible cities should ensure the integration of bike-sharing and public transport services. A good incentive can be a reduced fare structure for those who use both systems, another solution could be a common RFID card or any other technology to have access to both systems with one item.

1.3 Improving planning and enforcement

Real-time data availability opens new possibilities for planning while it is also crucial for monitoring and enforcing compliance with city policies (See bullet point No. 3 about how to monitor operator compliance).

- Establish data reporting standards:
  Cities should require operators to provide real-time operational data feed via a publicly accessible application programming interface (API) in a standardized format such as the General Bikeshare Feed Specification (GBFS).[77]
- User survey requirement
  Cities should require operators to distribute user satisfaction survey on a regular basis and share the results with them. This data may help analyze bike-sharing services and could highlight how to improve them.

1.4 Protecting users

Cities must protect users which means they should establish requirements for operators to educate users and to provide bikes and equipment that meet industry standards and ensure safety. The following actions are recommended by ITDP to reach these objectives.

- Clear safety information:
  Operators should provide easily accessible information about right cycling behavior and about general safety instructions. It is also important that operators should provide a platform which allows users to submit a maintenance report if the bikes are damaged or needs repair.
- Equipment standards:
  The bikes should meet industrial standards such as ISO 4210-2 to ensure safety and reliability. A liability insurance should also be required.
- User deposit refund protections:
  Several dockless bikeshare operators were unable to refund user deposits after the companies went bankrupt. Cities should take proper actions to protect user deposits like establishing a government or escrow account for deposits.

3. Monitor operator compliance

Data analyses can help to monitor operators' performance whether they achieve all the objectives mentioned above. Moreover, data analyses and further studies could contribute to the improvement of bike-sharing services. It is important to monitor data to supervise operations and check if it is in line with the requirements.
This aim requires cities to hire trained staff who can evaluate the system (preferably in real-time) by monitoring the operations and enforcing policies through fines or other penalties, if necessary. Accessible and verified operating data makes monitoring possible, therefore operators must provide appropriate data.

4. Evaluating and adjusting policies

The overall objective is to provide bike-sharing services accessible for all to increase the modal share of cycling. This could be achieved only with high level of service. Consequently, operator and user feedback should be analyzed on a regular basis to monitor the system performance. Cities should ensure that dockless bike-sharing services meet the set up requirements and goals. Continuous, progressive development like considering policies, new technologies and business models and proposing actions or adjusting policies, if necessary, is also crucial for success. (46)

[77] For more details about system data see chapter No. 2.5

Carplus Bikeplus – United Kingdom

Carplus and Bikeplus[78], a United Kingdom based organization works to change the way people travel to reduce the environmental impacts of transport and improve access to transport for all by promoting shared mobility.
Bikeplus[79] hosts a coalition of bike share operators working in the UK called *Bikeplus Operators and Suppliers Group*. The group has collected a set of recommendations for cities to help them to establish a bike-sharing system successfully. (155)

1. **Regulation**
   The group offers a nationwide recommendation instead of city guidelines such as Bikeplus Accreditation Scheme (see details below). (156)
2. **Transparent Competitive Process**
   A tender process is recommended. As the new schemes are privately financed a simpler, open "Request for Proposals" would work well.
3. **Licensing multiple operators**
   The group recommends the use of licensing where authorities consider allowing more than one operator.

Bikeplus Accreditation Scheme

Bikeplus created an accreditation scheme providing a set of standards for bike-sharing operators. The accreditation ensures that the operator fulfills the requirements for reliability while it also helps city authorities to understand how bike-sharing systems are designed and operated regardless of whether the operator has been granted public funding or just access to public space. The accreditation scheme reflects on the circumstances of the UK. Bikeplus regularly checks if the operator fulfills the requirements. (156)
The accreditation scheme is split into four sections with well-defined requirements:

1. **Business requirements**
   - Operators should have a formal organizational structure and operating experience.
   - Operators should submit an annual report about the performance of their services such as current number of bikes, stations, members, pricing structures and financial sustainability.
   - Operators should ensure ethical, social and environmental standards and fair work practices.
2. **Service provision requirements**
   - Operators offering self-service bike-sharing systems must fulfill the following requirements:
     - Easy self-service access (e.g. smart card, telephone application etc.).
     - Fair pricing.
     - 24/7 service all year.
     - Bikes must be available at key locations where there is costumer demand.
     - The system should have defined docking stations, and /or geo-fenced stations with wireless return detection or marked / agreed public stands.

[78] https://www.carplusbikeplus.org.uk/ (Cited: May 22, 2018)
[79] https://www.carplusbikeplus.org.uk/projects/bikeplus/ (Cited: May 22, 2018)

    - The operators of dockless schemes, when parking is allowed away from stations, must demonstrate that tools including geo-fenced restrictions, penalties, incentives and rebalancing are deployed to:
        - Ensure bikes can be returned to preferred locations as defined by the local authority to avoid obstructions.
        - Ensure bikes are not allowed to become excessively untidy.
        - Ensure parking is not allowed in locations that were identified as no-parking area by the local authority.
    - Operators should actively spread information about parking regulations to avoid undesirable parking behavior.
- Minimum specifications of bikes:
    - Bikes should meet the legal requirements of the UK (such as ISO 4210:2014 for e-bikes, lights and identification).
    - Bikes should be suitable for a wide range of users.
    - Other technical specifications like tyres, stands, luggage carriers etc.
- The number of bikes deployed should be in line with the demand:
    - Operators must not operate outside of the defined service area.
    - The number of bikes should meet the requirements set by the local authority.
- Operators must have a proper rebalancing system to ensure bike availability and avoid obstructions.
- Contactable operators, helpdesk and customer service.
- Operators must provide user information with terms and conditions.
- Operators should adopt ethical pricing strategies and should not support price dumping strategies.
- Deposits, and authorizations must be set at a reasonable level.
- In the case of withdrawal, operators should seek an appropriate closing down procedure to ensure customer satisfaction.
- Operators should be able to integrate their services with other local mobility services (E.g. integration with public transport or with other operators by using the same app or smart card).
- Operators must demonstrate compliance to data protection legislation.

3. **Maintenance and safety requirements**
    - Operators must have adequate insurance meeting the legal requirements of the country to cover the operator, user and third parties.
    - All bikes available must be roadworthy and regularly serviced and maintained.
    - Reactive maintenance (Operators should ensure minimum service requirements and collect abandoned bicycles).
    - Bikes and stations should be kept clean to protect the image of bike-sharing.
    - Promoting cycling safety (Operators should work with local authorities and support their initiatives to improve safety).
4. **Data collection requirements**
   Operators should provide data for Bikeplus, local authorities and third parties following a given template to support further analysis.
    - BikePlus annual bike share user survey which covers the following topics: number of users and trips, user satisfaction and travel behavior.
    - Regular quarterly report.
    - Open source real-time data feeds which are publicly available.
      (E.g. the data can feed real-time route planner applications or can support further researches.) (157)

European Cyclists' Federation (ECF)[80]

ECF is an umbrella federation for national cycling organizations that promote cycling throughout Europe. One of the many areas of activities of the ECF is enforcing cycling policy at European level. In June 2017, ECF launched Platform for European Bicycle Sharing & Systems (PEBBS)[81] with the involvement of service providers, cities and other relevant stakeholders.
In order to help cities, PEBBS created two supporting strategic policy documents in collaboration with other professional institutions and organizations such as UITP[82], NABSA[83] and Bikeplus[84]: *Policy Framework for Smart Public-Use Bike Share* (158) and the *Common Position Paper on Unlicensed Dockless Bike Share* (83).

ECF analyzes dockless technology with a complex, holistic approach called *"Cycling as a System"*. ECF identifies three pillars of a successful smart public bike-sharing system, which are 1.) Consumer (rider) choice and satisfaction, 2.) How the PBS system interacts with the city environment ("the public realm"), and 3.) Equipment providers and technological innovations that ensure lasting, sustainable service and access.

1. **Rider priorities**
   Services which meet user satisfaction are often successful, therefore the system's specifications should be adapted to them. The schemes should be safe, comfortable and reliable. It is important to have good connections with public transport and an integrated fare system. Easy access and data privacy are essential as well.
2. **City environments ("The public realm")**
   Public authorities and cities should create both physical and legal conditions which encourage the use of sustainable mobility modes considering climate change, air and noise pollution, public health, congestion and social inclusion.
3. **Technology / System providers**
   Private bike-sharing operators and competitive businesses provide new commercial opportunities from completely independent and competitive business models to public-private partnerships.

ECF suggests a set of approaches to manage dockless bikes and achieve business, public, and consumer / social goals:

1. **Registration / licensing / regulations**
   Agreement or licensing between the operators and cities is needed. The agreement should include specified service parameters and characteristics which could serve as a base for future monitoring and enforcement such as: fleet size, 24-hour customer service, bikes and equipment should follow all relevant national or international standards, data protection, public liability insurance and financial protection for costumers.
2. **Orderly streets**
   Cities should encourage more bicycle use. Therefore, they should provide more space for bikes (both for parking and moving). Operators should take greater responsibility and ensure orderly streets and avoid parking problems with special incentives for right user behavior or by providing functional public bike parking spaces.

[80] https://ecf.com (Cited: May 22, 2018)
[81] https://ecf.com/community/platform-european-bicycle-sharing-systems-pebss (Cited: May 22, 2018)
[82] International Association of Public Transport, http://www.uitp.org/ (Cited: May 22, 2018)
[83] North American Bikeshare Association, https://nabsa.net/ (Cited: May 22, 2018)
[84] https://www.carplusbikeplus.org.uk/projects/bikeplus/ (Cited: May 22, 2018)

3. **Riding (rolling) stock**
   Bicycles and their elements should meet the local legal requirements, safety and comfort standards.
4. **Servicing / Mechanical integrity**
   Operators should ensure that their bikes are kept in good condition and maintained on a regular basis. Smart technology provides new possibilities to optimize maintenance and make the processes more efficient.
5. **Re-balancing**
   Bike-sharing should be a reliable mobility option and the bikes should be around where the users expect them. Operators must have a proactive re-balancing process while cities should define minimum service requirements like identifying the key locations where the bicycles generally should be.
6. **Cooperation and consumer pricing / protection**
   Cities should consider establishing minimum fares to avoid price dumping and monopolistic behavior and to ensure fair-market competitive environment. Besides that, an interoperable ticketing system is desired with the integration of all available transport modes. A MaaS or other similar solution should be desired.
7. **Ensure exchange of data**
   Cities should have access to system data for monitoring and control as well as for research and planning. Operators should provide readily accessible data, like via General Bikeshare Feed Specification (GBFS) data standard.[85]
8. **Operator's ability to establish, perform and terminate operation**
   Cities should make sure that future operator(s) are able to provide reliable, long-term sustainable services. (158) (83)

The recommendations and examples presented above give a detailed overview about the main issues which should be considered for cities that want to provide successful dockless bike-sharing systems for their citizens. These examples show that cities are facing similar problems and they act in similar ways. In addition, there are some other noteworthy recommendations as well:

- **NABSA - Dockless Bikeshare Regulation Preliminary Guidance**[86]
  This guideline from North America was updated in April 2018 and it has a very similar structure as the previous ones. The recommendations cover the following topics: Permit or request for proposal, Service area, Fleet size, Parking, Equipment, Pedal-assist / e-bike specifications, Signage and advertising, Maintenance and operations, Equitable bikeshare, Insurance and Indemnity, Open data and reporting.
- **Alta Planning + Design - Dockless Bike Share Planning**[87]
  Dockless technology differs from station-based systems because of its additional complexity, and therefore a special planning approach is needed which ensures a win-win situation for users, cities and operators. The following issues should be taken into consideration according to Alta's New Mobility Group[88]: Program goal setting, Policy framework, System Boundaries, Bike parking, Integrating programs, Continuous monitoring, improvement and innovation

In the following part of the chapter I analyze dockless bike-sharing technology to evaluate its advantages and disadvantages.

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[85] For more details about system data see chapter No. 2.5.
[86] NABSA - North American Bikeshare Association. The guidance is available here: https://nabsa.net/guidance/ (Cited: May 29, 2018)
[87] https://blog.altaplanning.com/the-dockless-bike-share-revolution-eb62698d81f8 (Cited: June 1, 2018)
[88] https://altaplanning.com/alta-innovation-lab/new-mobility/ (Cited: June 1, 2018)

5.5 Analysis of dockless bike-sharing technology

I chose SWOT analysis to identify the internal and external advantages and limitations of dockless technology in a systematic way. The analysis covers the most important characteristics from different viewpoints such as user experience, operational aspects, funding and planning procedure.
My original approach with this analysis was to identify the hidden opportunities and threats of dockless bike-sharing technology and multi-operator models with private actors. As I wanted to evaluate the technology and the operating model themselves rather than actual providers and their services, I carried out the assessment analysis from a scientific or theoretical point of view. However, there are some exceptions. In some cases, I reflected on recent happenings and existing market actors to make the analysis up to date, more complex and realistic. Chapter No. 5.2 provides more insights about dockless bike-sharing operators and their services.

As a result of limited data resources and published researches, there are some aspects which are only partly or not mentioned at all in this analysis. To have a more comprehensive work, further research is needed and at least the following aspects should be involved and discussed:

- **Financial and economic sustainability (in case of new startups and market actors)**
  There are some articles, researchers and organizations which state that bike-sharing startups often have no long-run sustainable business model and they are very capital intensive. Bike-sharing business turned into a competition based mostly on ability to raise capital. Some companies already went bankrupt. (159) (160)
  Other articles and companies state they will be profitable in the long term by user revenues. Some articles believe that travel data will generate the profit. (51)
- **Effects on local economy**
  The European Bicycle Manufacturers Association states that large scale bike-sharing providers are directly threatening the bicycle industry by disrupting supply chains and driving up the price of bike components. (160)
  However, if dockless bikes were produced and maintained locally, local bike industry could experience a boom as well. Moreover, local businesses could be involved in rebalancing too. (161)
- **Effects on public interest**
  Privately-funded bike-sharing services might have different priorities such as economic drivers and profitability rather than providing a reliable, accessible and affordable public service. However, if private operators would like to make profit, they should ensure long-term sustainability and attract users. Further studies are needed to examine the advantages and drawbacks of this business model. (78)

SWOT analysis of dockless technology

The following table summarizes the key findings of the SWOT analysis. On the following pages I specify the details of the analysis and I explain each aspect.

Strengths: • Lower implementation costs • Less time-consuming planning and implementation procedure • No or less need for public funding • Geo-fencing provides great flexibility • More accessible and visible bike-sharing • GPS-tracked smart bikes • All functions are available within an application • Great potential for quick and affordable development and expansion	**Weaknesses:** • Parking problems • Dockless bikes are more exposed to vandalism • Limitations of electric-assist mode • Limited access • Docking stations have their advantages
Opportunities: • Private companies with strong financial background and enormous fleets • Globalization, digitalization and their effects on mobility habits and services • Developing data analysis methods • Market competition	**Threats:** • Low market entry barriers • Rat race among providers • Vandalism and parking problems • Data security and privacy • Economics' "Free Rider" problem • Bike-sharing as a public service

Table 12: SWOT analysis of dockless bike-sharing technology

Internal factors

Strengths:

- **Lower implementation costs**
  As docking station infrastructure and kiosk machines are not necessary, implementation and planning costs are lower than in the case of station-based systems. (35) Dockless schemes use basic IT solutions which can be developed relatively cheap compared to docking station infrastructure costs. Although dockless bikes should cost the same amount as most of station-based bikes have an on-board computer and GPS module as well, mass production could dramatically depress the prices of dockless bicycles. (162)
- **Less time-consuming planning and implementation procedure**
  Less time-consuming legal approval procedure compared to station-based systems as there is no need for docking station infrastructure which requires longer planning and authorization procedure. Implementation could be carried out in a shorter time frame as well as the construction of stations, if necessary, is less complex.
- **No or less need for public funding (private companies with private funding)**
  In most cases the implementation and operating costs of bike-sharing systems have been covered by capital expenditure. Market liberalization and competition could reduce both operation and implementation costs as well as usage fees. Therefore, a lower amount or no public investment would be needed.
  Private bike-sharing companies and their private funding could cover capital and operating costs. Thus, the need for public subsidize could be reduced or could be

unnecessary and eliminated. Private financing would make bike-sharing system expansion possible in a lot of cities where otherwise it would not be an option.
It is worth to mention that a proper regulatory framework is recommended to regulate market actors and market competition to ensure high quality of service.

- **Geo-fencing provides great flexibility**
  Dockless technology and geo-fencing[89] provide great flexibility for users, operators, cities and for future development as well:
  - Users can leave the bikes directly at or close to their destination. No more annoying full or empty stations (considering physical limitations of available space for bikes and reallocation). Users can leave the bikes where it is the most convenient for them.
  - Operators can easily adjust their services to the actual user needs as the geo-fenced service area or the virtual stations can be easily modified. In the case of physically marked semi-dockless systems (e.g. Urbo) it is easier and legally less complicated to relocate "light" stations compared to the relocation of traditional docking stations and kiosks.
  - Geo-fencing provides the possibility for cities and public authorities to have control on the use of public spaces and public bikes. Cities can monitor the location of the bikes and enforce local regulations.
  - Cheap and easy implementation makes future development and expansion more flexible as well because service area could be enlarged easily.
- **GPS-tracked smart bikes**
  Smart bikes with GPS tracking and smartphone operated locks provide easy access to users and hold other opportunities for operators and professionals. Besides geo-fencing, GPS-tracking provides accurate, detailed and robust travel data.[90] The analysis of travel patterns could help operators, planners and decision makers to improve and optimize mobility and bike-sharing services. Real-time GPS tracking provides the possibility for smart management. In addition, the potential uses of travel data analysis are endless as data mining and big data analytics are evolving rapidly.
- **More accessible and visible bike-sharing**
  Dockless bike-sharing systems can be implemented easily and can be adapted to the actual user needs in a more flexible way. Therefore, easy to implement, large scale dockless systems could significantly improve bike-sharing accessibility, thus means people would have more mobility options and improved access to jobs, schools and other destinations. (46)
  Most docking stations accommodate at least 15-20 bikes and in an optimum system stations are located not farther than 200 m from each other. Dockless bikes or parking areas for dockless bikes could easily be placed more densely. Dockless

[89] A geo-fence is a virtual perimeter for a real-world geographic area. A geo-fence could be dynamically generated as in a radius around a point location (e.g. virtual or semi-dockless bike-sharing stations), or a geo-fence can be a predefined set of boundaries (such as neighborhood boundaries or bike-sharing operating area).
The use of a geo-fence is called geo-fencing. A zone is defined by GPS or RFID and it registers when a mobile device like a smart bicycle enters or leaves the defined zone. This activity could send an alert to the user's device (smart phone or other equipment) as well as a message to the geo-fence operator. It helps to quickly and effectively manage connected devices like shared bicycles in the city's public space. Geo-fence could serve both the city and its citizens and it would not only regulate the use of shared bicycles but also the functioning conditions for the operators. Geo-fencing enables the enforcement of regulation of public spaces.
(The definition is based on Wikipedia (180) and on VeloCittà paper (179))

[90] In most of the fourth generation station-based schemes GPS tracking is a general feature as well, which provides similar possibilities.

parking areas are more suitable for fewer bikes (5-10) as they are cheap and do not need any special infrastructure or equipment like computer kiosks.
Docking stations do not fit everywhere as they need a relatively big space, which limits their implementation possibilities and flexibility. Dockless bike parking zones could be more compact and smaller.

- **All functions are available within an application (hiring, payment etc.)**
  In our digitalizing world more and more people use smartphones which offer a lot of opportunities. Standardization and integration of different services has been a major issue for a long time (e.g. smart card integration, MaaS systems etc.). An app can cover all the necessary functions from registration through hiring to on-line payment methods or call-center services. This makes the use of the system easy and attractive. It shortens the registration and hiring process to a few taps on a smartphone. On the other side, integration and one-way access has some drawbacks as well (see Weaknesses / Limited access).
- **Great potential for quick and affordable development and expansion**
  All the above-mentioned strengths ensure the potential great success of dockless technology. From the implementational point of view it is relatively quick and easy to implement compared to planning and building docking stations which could last longer. Moreover, the implementation and operation require less capital investment. Usage fees are generally lower as well. (163)

Weaknesses:

- **Parking problems**
  As it was mentioned in subchapter No. 5.3, arguments about parking problems, blocked sidewalks and public spaces occur frequently. As docking stations are not part of the system, users can leave the bicycles wherever they want (users ideally should follow local parking regulations). Although semi-dockless systems have marked, designated parking areas, non-compliant behavior can cause problems in this case as well.
  There are some semi-dockless systems which require their users to lock the bikes to bike stands, which eliminates the problem of easily falling bicycles, especially in windy weather, but it limits system flexibility.
- **Dockless bikes are more exposed to vandalism**
  As the bicycles are not attached to a fix object (docking station) they can be moved and be stolen easier. More attention and new solutions should be adapted to prevent theft and vandalism.
- **Limitations of electric-assist mode**
  Electric-assist bike share has the potential to provide more accessible and convenient services. Unfortunately, it is a more complicated and resource-intensive task to charge or change batteries of dockless bicycles than charging docked ones which could be easily wired and connected to the electrical grid.
  Despite this limitation there are some initiatives to operate dockless e-bikes (such as Jump Bikes[91] or LimeBike[92]). These companies have their own service teams who take care of the batteries.
  There is another noteworthy solution for e-bikes which is called BYOB or Bring Your Own Battery. This solution requires users to bring their own battery which they can use during their journeys. The bikes without batteries function as regular, pedal powered bikes and with batteries the electric assist mode can be used.

[91] https://jumpbikes.com (Cited: May 17, 2018)
[92] https://www.limebike.com/ (Cited: May 17, 2018)

JCDecaux[93] has developed the first BYOB scheme in 2015, it has been part of a docked program. CycleHop[94] has introduced HOPR electric bicycle, the first dockless e-bike with a portable power pack in March 2018.

- **Limited access**
  In the case of recently emerged dockless bikes, using a smartphone application is the only way to access the service. Although smartphone applications and integration provide plenty of possibilities and easy access, this approach has also certain drawbacks. Those who do not use smartphones cannot access the service as it is the only way to hire a bike. Discharged phones could be also a problem.
- **Docking stations have their advantages**
  Station-based systems offer several important advantages which are only true for some dockless bike-sharing systems. Docking stations and the mass of bicycles make the system visible and attract user interest, especially if all the shared bikes have the same design. Fixed stations also offer reliable services as users can find the bicycles always at the same spot and they do not have to search for a bike in an application. (44)

External factors

Opportunities:

- **Private companies with strong financial background and enormous fleets**
  Many investors see great opportunities in the growing market of dockless bike-sharing services. As it was described earlier, there are several market actors who provide reliable services and have large-scale capacities. These market conditions provide good opportunities to expand shared bicycles in cities.
- **Globalization, digitalization and their effects on mobility habits and services**
  During the last five years the number of smartphone users has tripled up to approximately 2.5 billion people. It is estimated that the growth will continue. In 2017, more than half of the European population used smartphones. (164) (165) As the number of smartphone users is significantly growing, smart bike accessibility is increasing as well.
  The fourth industrial revolution and digitalization reshape the way we think and communicate, as well as production, employment and education. Smartphone application based on-demand mobility services are emerging worldwide. These new solutions have great effects on people's mobility habits. (166) New technologies could also develop the existing dockless schemes, broaden their expansion and eliminate their weaknesses.
- **Developing data analysis methods**
  There are several examples when data science supports smarter and more efficient urban and transport planning. Analysis can highlight problems which would remain hidden with traditional methods. High volume of data about cycling patterns provided by dockless bikes and developing data analysis methods at the same time could help planners optimize our mobility systems and create more attractive and welcoming environment for cycling. The following sources highlight some possible applications. (167) (168) (169) (170) (171) (172)

[93] http://www.jcdecaux.com/press-releases/jcdecaux-launches-self-service-electric-bikes (Cited: May 17, 2018)

[94] http://cyclehop.com/hopr-introduces-the-first-dockless-electric-bike-for-bike-share-with-a-portable-power-pack-eliminating-the-need-for-expensive-charging-infrastructure/ (Cited: May 17, 2018)

- **Market competition**
  In the past, in most cities there was only one system available which was funded and subsidized by public money. Recently, as private start-ups have developed, new market actors and business models hit the market. Market competition (with proper regulation) has positive effects. Companies that want to survive the fierce business competition, may adopt new technologies and reduce prices, conduct education and training programs. There is a negative side of market competition as well as it is shown in the table below.
  However, in this analysis market competition is regarded as an opportunity because it offers new possibilities for innovation, spreading bike-sharing systems and scheme expansion.

Positive effects	Negative effects
• Lower prices for all • Better service quality • More choices and variety • More flexibility to operators • More innovation • Better competitors in global markets	• Unfair methods of competition • Ignoring social inclusion and equity • Ignoring regulations, more likely violate the law • Oversupply of bikes • Less emphasis on safety and user protection

Table 13: Commonly mentioned pros and cons of market competition in general, regarding dockless bike-sharing services (173) (174) (126)

Threats:

- **Low market entry barriers**
  Lack of agreement between cities and bike-sharing providers could cause and has caused various problems. General low entry requirements or lack of service regulations led to several problems in various cities around the world. After a while cities and operators realized that they should solve these problems and act by establishing proper regulations (see chapter No. 0.).
  Bike-sharing should be considered as a public service which serves the basic mobility needs of citizens. Therefore, dockless bike-sharing operators must provide reliable services. Bikes should be available for a broad range of users, especially regarding social and equity aspects. Service conditions should be guaranteed as well such as pricing, accessibility, availability of bikes etc. Once a company enters the market, its services should fulfill the legal requirements.
  Another problem related to low entry barriers is the lack of formal tendering procedures which help cities choose the most favorable offers. (63)
- **Rat race among providers**
  In the same respect as in the previous point, rat race among dockless bike-sharing providers and low entry barriers caused parking problems, public space occupation and oversupply. In 2017, free-floating bike-sharing in China and in several European cities went through a bubble and burst effect. The biggest Chinese market actors flooded cities with their smart bikes without any public license or official agreement. (175) The rat race was mainly about catching as many users as possible by reducing the prices to destroy competitors. This led to chaos, lack of maintenance, rebalancing and bankrupt startups like Bluegogo. As a reaction, many Chinese and European cities started to set up regulations to avoid such a phenomenon.
- **Vandalism and parking problems**
  While all bike-share systems face theft and vandalism, the easy access to dockless bikes makes it even worse for them. It is hard to avoid the negative effects of deviant users who do not respect the terms of use.

However, docked systems have faced vandalism as well. For example, Santander, the sponsor of London's public bike-sharing system, was forced to close temporarily some docking stations in Milton Keynes after more than half of its bikes were damaged or stolen. (176)

- **Data security and privacy**
  As the financial background and long-term sustainability of dockless bike-sharing startups is not always clear, some experts argue that the main driver of the rapid expansion is travel data. Data collection is criticized by several articles as the main investors could benefit most of the collected data. (119)
- **Economics' "Free Rider" problem**
  "In economics, the free-rider problem occurs when those who benefit from resources, public goods, or services do not pay for them, which results in an underprovision of those goods or services." (177) For example, bike-sharing operators use public spaces and generate profit, even though they do not pay for that. All direct and indirect costs should be taken into consideration to not socializing private costs. This phenomenon should be avoided, and a sustainable and equitable use of public resources and public spaces should be fostered. (158)
- **Bike-sharing as a public service**
  It is recommended that bike-sharing services should be treated as a public service, as a public transportation mode. The services should be prioritized by public interest and local needs, rather than by profitability as it might have opposite effects. (78) Private operators should ensure long-term reliability for boosting public confidence.

6 Findings

This chapter summarizes the findings and conclusions of the thesis. *As it was described previously, many forms of bike-sharing systems exist. There are several solutions to provide bike-sharing services but there is no one solution that fits all. For a better understanding I carried out a comparative assessment of state-of-the-art 4th generation station-based systems and dockless ones. Besides that, this chapter introduces a multi-operator model for bike-sharing. The discussed research questions are as follows.*

RQ-4	*How should cities treat the dockless bike-sharing boom and their rapid expansion? Would market liberalization and multi-operator models be feasible options for bike-sharing? What kind of regulations and operating models would be necessary for a successful, small-scale market liberalization on city level? What are the possible risks of inaction?*
RQ-5	*What are the main differences between state-of-the-art, 4th generation, station-based bike-sharing systems and dockless ones? Do these technologies compete or rather complement each other?*

6.1 Comparative assessment of dockless and station-based bike-sharing

Both dockless and station-based bike-sharing technology have their own advantages and disadvantages, as it can be concluded by the previous chapters and the introduced characteristics of the two systems. It is necessary to examine the opportunities of the two technologies to find out under what kind of circumstances they could perform best. I carried out a simplified assessment to conclude and compare these two types of bike-sharing systems regarding implementational and operational aspects and user needs. I compared state-of-the-art 4th generation station-based systems with dockless ones.

As a first step, we should examine the needs of operators, cities and users who consider different aspects and factors of bike-sharing services as important ones. (178) The following list summarizes these aspects from the operators' and users' point of view:

- Density of bikes and stations is important both for the operators and users. Rebalancing the bikes is more effective if the system is dense and the trips made by the users contribute to the system equilibrium, unlike in the case of those systems where most of the trips have the same destination (like all the users are heading to the same direction in the morning). Density is important for users too as the more bikes and stations are available, the more accessible and reliable the bike-sharing system is.
- Affordable fare structure is important for both the operators and users as well. The more affordable the bike-sharing system is, the more people tend to use it as the bike-sharing system becomes a possible mobility option. The more people use the bicycles, the more revenues are generated.
- Accessibility of the system regarding opening hours (whether the bikes are available all day, all year or not) and easy registration and payment methods is also important for users. At the same time, the utilization rate is important for operators in terms of the number of rents per bicycles or in total.
- Innovation, electric assisted bicycles, real-time information and diverse payment and access methods make bike-sharing more attractive and accessible, therefore these factors are important for users. It should be noted that the complexity of the system influences the investment and operating costs.

- The characteristics of the city and its mobility system such as density, level of motorization, modal split and topography, legal framework play important roles as these are the main determinant factors for successful implementation.

Some of the aspects mentioned above are not under direct influence of system design (such as the topographic conditions or fare structure) and there are others which are significantly differ depending on whether the system is station-based or dockless. The comparative assessment focuses on the latter characteristics which are summarized in the tables below.

Station-based bike-sharing provides reliable and comfortable services as the bikes can be found always at the same locations, at the docking stations. Moreover, the bikes are parked orderly which ensures the right-way of public space use. However, it is quite resource intensive to install bike-sharing stations due to time-consuming planning and implementation, and expensive infrastructure. In dense cities, finding a place which is big enough for a docking station with 15-20 bike is not always easy either. Especially in those cases when the space should be taken from cars, like converting parking places to docking station. (This problem occurs worldwide, even if it was an efficient way to reduce car use while providing a suitable alternative.)
Meanwhile, dockless bikes have their benefits where station-based systems are weak. Dockless systems offer an easy to implement, cost-effective solution compared to docked ones. Therefore, dockless bikes could serve less dense areas more economically. Although dockless technology has greater potential for large-scale, rapid development, the weaknesses of dockless bikes lay in parking problems which can cause major problems in dense cities.

	Station-based bike-sharing	Dockless bike-sharing
Strengths	• **Orderly parked bikes and managed public spaces** Docking stations define the places where the bikes should be parked while slots secure the bicycles and keep them in order. • **Long-lasting infrastructure** Heavy infrastructure is less exposed to vandalism and implies permanence and stability. • **Stations and system image promotes cycling** The mass of bicycles at docking stations attract people's interest.	• **Scalability and flexibility** Lower capital and implementation costs as dockless systems do not depend on special infrastructure and might not require large space in one place for docking stations. These make large-scale development easier. • **Quick implementation** Requires less preparatory work and planning, while geo-fencing provides great flexibility to adopt the services to user needs continuously. • **Dockless bikes could serve less dense areas economically** Due to lower implementation and operating costs, and flexible deployment.
Weaknesses	• **Spatial and financial challenges of implementation** Docking stations and special infrastructure have their higher costs and they might require more space in one place. • **Time-consuming implementation** Docking station placement, planning, authorization and implementation are more time-consuming. • **High operating and maintenance costs** Dockless bike-sharing systems might have higher operating costs.	• **Dockless bikes are more exposed to vandalism** As the bicycles are not secured to a fixed object (except lock-to technology). • **Improperly parked bikes** Without proper regulations and incentives bikes are not always parked orderly and it might disrupt others. • **High operating costs of dockless e-bikes** As parked dockless bicycles are not connected to the power grid, charging the batteries is a more resource-intensive task.

Table 14: Comparison of station-based and dockless bike-sharing systems regarding implementation and operation (Main sources: (47), (111))

	Station-based	Dockless
Strengths	• **Fixed stations provide comfort and reliability** Users can find the stations always at the same locations and do not have to look for a bike. That makes the services reliable in all cases and fixed locations fit into daily routines easily. • **Fixed stations can be accessed without smartphones** Station-based systems are accessible if the user does not have internet connection or a smart phone.	• **Flexibility** Users can leave the bikes where it is the most convenient for them within the service area (semi-dockless systems might limit this advantage). • **Convenience for smart phone users** All functions are available within an application which provides convenient services for those who use a smart phone.
Weaknesses	• **Inflexible services** Users should leave the bicycles at the dedicated docking stations which might limit accessibility and flexibility, especially in less-dense parts of the city.	• **Limited access** Accessing the system requires internet connection and a smartphone which might be a limitation in some cases.

Table 15: Comparison of station-based and dockless bike-sharing systems from a user point of view (Main sources: (47), (111))

Complementation or competition? – Hybrid systems

Both dockless and station-based systems have their advantages and disadvantages. Hybrid systems, the mix of the two models, could strengthen the benefits of both technology while reducing the drawback effects of them. Expanding the bike-sharing system is easier, faster and cheaper with dockless technology, it can complement docked systems. There are two possible applications for a hybrid system.
The first and simpler solution is the semi-dockless model as it was discussed in chapter No. 4.3. In that case, dockless bikes should be parked in a designated parking area or should be locked to a defined object without the need for special docking infrastructure.
The other model could be another hybrid system where docking stations keep public spaces in order which is important in dense areas, while dockless bikes could serve less dense parts of the city where the implementation of docking stations would not be efficient. In that case, the bikes could be used as dockless bikes in the outskirts and they must be parked at designated stations or parking areas in more dense parts of the city.[95] (179) (111)

Station-based and dockless bike-sharing systems might compete as well, especially in those cities where the station-based systems do not have a dense network of stations and a large-scale dockless bike-sharing arrives. Even different dockless bike-sharing operators could compete. Whereever these kinds of competitions arise, and it is expected that they could be beneficial, cities should ensure proper conditions for a regulated, fair and fruitful competition. The following chapter introduces a proposed framework for a multi-operator model for bike-sharing.

6.2 Multi-operator model for bike-sharing

The new business model brought by the dockless bike-sharing boom changes the way of how bike-sharing systems operate in cities. The former single-operator model is changing as well and the number of cities with more than one provider is increasing.
Cities' bike-sharing systems can be completely private or the combination of public and private. Cities could also combine station-based and dockless technology, as it was discussed in the previous subchapter. Even two or more operators could provide dockless

[95] Some hybrid systems already exist, the solution provided by SocialBicycles is quite similar.

bike-sharing services in the same city. Cities should decide whether operators should share the same service area, or different service areas should be defined for the operators.
A multi-operator model creates competition which encourages innovation and continuous improvement according to the needs of cities and users. Besides that, private companies and private investment can reduce or even eliminate the need for public investment and public subsidies for operation.
However, based on global experiences, private companies and unregulated market could cause several problems as it was mentioned in the earlier chapters. Cities should ensure that private companies provide reliable bike-sharing services which serve the needs of users and the desires of cities. To maximize the benefits of the multi-operator model and avoid the drawbacks of unregulated market, proper regulations should be adapted by cities where fair and beneficial competition can occur.
A Memorandum of Understanding (MoU) or another similar document which sets the terms and understanding between the operators and the cities is necessary as well. The agreement should be based on the mentioned regulations.
A wait-and-see approach and low entry barriers from cities' side could lead, and actually led, to various problems that can be avoided. Cities should define certain services they want, and operators should adapt to those requirements. Collaborations between operators and cities ensure reliable service for users and creates a predictable operating environment for businesses at the same time. (47) (158)

Some general recommendations for cities are as follows:

- It is important to mention that the multi-operator model for bike-sharing systems is not a solution which fits to every city. Cities should decide, based on the given conditions, whether multi-operator model is a good option for them and they should tailor it to the local conditions and desires. So, the first step would be a feasibility study to examine these questions.
- Political and professional support are essential for a successful bike-sharing system. Therefore, cities, future operators and other relevant stakeholders (like public transport operators) should work together from the beginnings. Moreover, citizen involvement should be also an integral part of the preparatory work and during the operation as well. Monitoring of user feedback should be enhanced, and the services must meet user needs.
- Cities should treat bike-sharing as a public service and as an integrated part of the city's mobility system, which enhances intermodal trips combined with public transport for longer distances and promotes cycling for shorter distances. Even if the bike-sharing system is privately-funded, economic interests and profitability cannot be allowed to take precedence over public interest.
- The launch of a bike-sharing service requires proper, safe and attractive cycling conditions. Therefore, this issue should be emphasized as a crucial momentum for success. Marketing, promotion and education should play important roles as well.
- Cities should launch a system which has a sufficient size in terms of density of bikes and covered service area. A too small service area or less dense system might not attract enough users which does not necessarily mean that bike-sharing as a service could not be successful with other parameters and more extensive preparatory works.

Regulations for multi-operator model

Cities should focus on proper regulations and pilot programs rather than banning dockless bike-sharing operators without examining the possible benefits. A test phase could be suitable in all cases and after a several month long[96] pilot program cities could decide whether a multi-operator model or dockless technology would be suitable for them and they could decide what kind of regulations and operations would fit their needs best.
Chapter No. 0 discussed the details of implemented regulations the topics which should be covered by the regulations. The regulation should be outcome-oriented and should define the requirements of the desired high-quality services and it should allow market competition of multi-actor operation and let private companies do the rest. An outcome-oriented approach and proper regulatory environment are needed to ensure favorable conditions and flexibility for innovation. Operators need this kind of flexibility for service and business model improvement while cities somehow should coordinate and control these processes. The topics which should be covered are as follows:

- **Fair and beneficial competition**
  The optimal and maximum number of bicycles and operators should be defined to avoid oversupply and optimize the bike-sharing supply in line with demand. Too much competition can be a problem while the other end, a small system and insufficient density could lead to failure as well.
- **General service requirements**
  An out-put oriented approach should be followed by defining the minimum service requirements such as bicycle availability, required minimum and optimal number of bicycles in each pre-defined area (redistribution and rebalancing); required standards for bicycles and equipment (safe, comfortable or pedal-assisted bicycles which meet local standards, GPS tracking and geo-fencing etc.); maintenance; fare structure; insurance; helpdesk and customer service etc.
- **Public space management**
  The main driver of this topic is to ensure orderly parked bicycles and avoid public space occupation. Incentives and penalties should be established to avoid vandalism and improper parking. The task of remove the abandoned bicycles should be dedicated as well. User education and marketing are also crucial which encourage positive attitudes towards bike-sharing.
  It is worth to mention that improperly parked bikes might cause public nuisance but the bikes themselves are not the main cause of public space occupation in most cities. An integrated and more complex approach would be more beneficial, thus cities should regulate bike-sharing, other vehicle-sharing services and mobility options at the same time. The focus should be on equity of public spaces and space should be dedicated by considering the desired future of the city and in accordance with the defined future modal share and mobility trends (in line with the SUMP or such document of the city). In simple terms, if cities want to encourage the use of bicycles, they should dedicate more space for cycling.
- **Integration**
  Bike-sharing services should be integral parts of the mobility system of cities regarding both physical and administrative integration. Common or integrated fare structure is desired in case of multi-operator model as well. Customers should not be confused by multiple operators, therefore a common platform should be developed which provide access to all services (like an application which involves all operators and all of their bicycles are shown on one single map).

[96] The pilot should be long enough for collecting the necessary data and experiences to draw the final conclusions. Based on the collected examples, the pilot generally is 3-12 month long.

- **Equitable access to bikeshare**
  Bike-sharing should be accessible for all. The aim is to increase the equity of bike-sharing and to provide accessible services regardless age, gender, income etc. More than one payment and access methods should be offered to make the bike-sharing services more attractive and accessible for those who do not use a smartphone.
  Favorable and flexible fares and membership options are crucial as well.
- **Increase the (social) responsibility of operators**
  Operators should focus on customer awareness and education in a holistic way. Besides promoting or incentivizing proper user behavior and traffic safety, cycling and sustainable mobility habits should be promoted as well.

- **Data sharing and data protection**
  Operators should provide real-time data which makes control and monitoring possible. It is also essential for future planning and for other applications such as real-time route planners or for common platforms. The protection of user data should be ensured as well.

Only those operators should be allowed to provide their services who fulfill the requirements. Cities should coordinate the accreditation of operators and should monitor their performance. Operator and user feedback should be analyzed on a regular basis and, if necessary, regulations and developments should be adapted to them.

7 Case studies

The aim of the case studies is to examine whether dockless bike-sharing technology is a suitable option for Budapest and Valencia. To answer this research question, I analyzed the existing bike-sharing services and the two cities themselves. Based on the main findings of the previous chapters I set up recommendations on how to improve MOL Bubi in Budapest and Valenbisi in Valencia, preferably with dockless technology. The discussed research question is as follows.

RQ-6	*What are the main characteristics of the bike-sharing systems in Budapest and Valencia? What should be improved to provide better bike-sharing services? Is dockless bike-sharing technology is a suitable option for these two cities?*

7.1 Budapest and Valencia

I chose these two cities for the case studies for practical reasons. I live and study in Budapest and I write my thesis in Valencia during my exchange-semester. Budapest and Valencia are two different cities regarding their characteristics such as urban structure and dimensions, population, modal split etc. Although there are no parallels or similarities between the two cities at first sight, both cities have favorable conditions for urban cycling regarding their size, density, climate and topography. Moreover, in both cities the number of commuters is high. Budapest and Valencia attract a lot of students and tourists who are potential bike-sharing users as well. (180) (181)

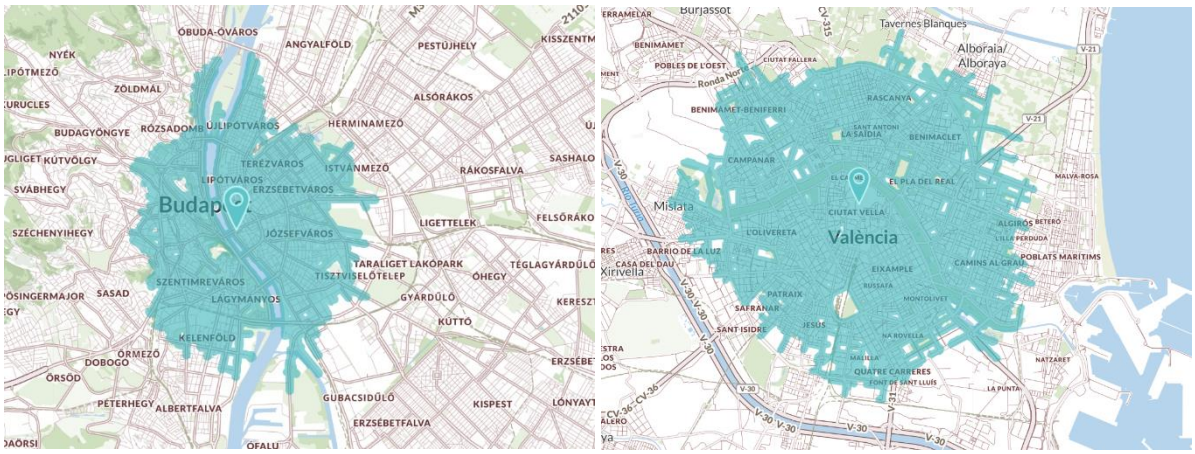

Figure 19: The maps show 15-minute catchment area of moderate cycling in Budapest and Valencia. As it is illustrated, both cities' sizes are favorable for cycling. (Source of maps: https://map.bikecitizens.net[97])

The table on the next page summarizes the main characteristics of both cities.

[97] Cited: June 5, 2018

		Budapest	Valencia
General overview			
Population	City	1.73 million	0.78 million
	Urban area	2.93 million	1.84 million
Area	City	525.2 km^2	134.65 km^2
	Inner city	approx. 10km^2	approx. 3 km^2
Density	City	3 351 inhabitants /km^2	5 800 inhabitants /km^2
	Inner city	Data Not Available	Data Not Available
Demography		Budapest has an aging population. The mean age is 42.8 and the mean life expectancy is 77.18. 70% of the population is between 15 and 64 years.	Aging population with the life expectancy of 82. The mean age is 44 and 66% of the population is between the age of 15 and 64. About 12% of the registered population has other nationality than Spanish.
Economic and financial situation		The unemployment rate is 3.5% and the GDP per capita is approx. EUR 23000.	16.6% of the active population is unemployed. The GDP per capita is approx. EUR 22000.
Topography		Mostly flat, Buda side is partly hilly.	Flat with marginal altitude differences.
Tourism		10 million overnight stays in 2017.	4.8 million overnight stays in 2017.
Climate		Continental climate with a daily mean temperature of 11°C and 116 precipitation days a year (593 mm).	Mediterranean climate with a daily mean temperature of 18,4 °C and 44 precipitation days a year (454 mm).
Transport system, mobility situation			
Modal split [%] walking / cycling / PT / car		18 / 2 / 45 / 35	41 / 4 / 23 / 32
Public transport		Extensive PT network in Budapest with 4 metro lines, 36 tram lines, more than 200 bus and trolleybus lines. Extensive suburban network. Frequent day and night services. Real-time passenger information and route planner application. Outdated, inflexible paper-based tickets and passes.	Extensive metro - suburban train network with 9 lines. Approx. 60 bus lines. Real-time passenger information and route planning. Frequent day services with 12 night buses. Developing PT services with new hybrid autobuses. Partly integrated services with different operators and smart cards.
Shared mobility		Bike-sharing (one station-based and one dockless scheme) Car-sharing Motorbike-sharing services	Bike-sharing (station-based) Motorbike-sharing Car-sharing rarely exists due to high level of motorization

	Budapest	Valencia
Traffic safety	2.65 road traffic injuries per 1000 capita in 2017 (total 4 578). 3.23 traffic death per 100 000 inhabitants (total 56). Approx. 0.28 injured cyclists per 1000 capita annually (2% cycling share, average 491annual injuries between 2013 and 2017).	5.1 road traffic injuries per 1000 capita in 2016 (total 3 975). 1.4 traffic death per 100 000 inhabitants (total 11). Approx. 0.4 injured cyclists per 1000 capita in 2016 (4% cycling share, 311 injuries in total).
Number of vehicles	360 passenger cars per 1000 capita (total 633 554) 14 motorcycles per 1000 capita (total 25 300)	441 passenger cars per 1000 capita (total 344 280) 72 motorcycles per 1000 capita (total 55 868)
Existing bicycle infrastructure	The main cycling network is approx. 300 km long, which means that the average density is 0.57 km/km^2 throughout Budapest.[98] The network is mainly composed by bicycle lanes, bicycle paths and shared paths. Two-way cycling in one-way streets and shared bike and bus lanes are also common.	The main cycling network is 131 km long, which means the average density on city level is almost 1 km/km^2. The length of *ciclocalles* (cycle streets) is 43.5 km. Two-way separate bicycle paths dominate the city's streets.

Table 16: The main characteristics of Budapest and Valencia[99]

7.1.1 Budapest

Budapest is the capital of Hungary and it functions as a political, cultural, economic and educational center of the country. The city is the capital of Pest County as well. Budapest is the largest Hungarian city regarding its territory and population. 1.7 million people live in the city, while 2.5 million live within the borders of the metropolitan area in 81 municipalities. Budapest has a territory of 525 km^2 while the metropolitan area is around 2500 km^2.
The topographical conditions of Budapest are mostly favorable for cycling. The city is basically flat, only the center-western part of the city is hilly which makes cycling less attractive there. However, to electric assisted bicycles these hills do not pose a major obstacle.

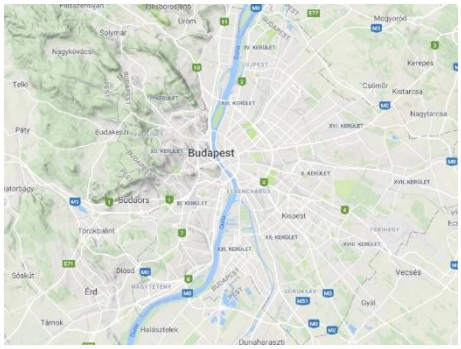

Figure 20: Topographic map of Budapest (Source: Google Maps[100])

[98] As the urban structure and density varies on a large scale within the city, it is hardly a relevant indicator for comparison.
[99] The main data sources are the Hungarian and Spanish statistical offices, Wikipedia pages and other electronic documents.
[100] https://www.google.com/maps (Cited: June 17, 2018)

Budapest has a continental climate with a mean daily temperature of 11 °C. The average annual precipitation is 593 mm with 116 precipitation days a year. The mean number of annual sunshine hours is approx. 2040. (182)

The cycling movement of Budapest is world famous as the former Critical Mass[101] and present I Bike Budapest movement[102] is one of the biggest bicycle marches around the world, which attracts tens of thousands of participants every year.
There are some key non-governmental organizations which enforce sustainable and bicycle-friendly city and transport development. Without aiming to provide an exhaustive list, the key non-governmental organizations are the following:

- **Hungarian Cyclists' Club**[103]
  The Hungarian Cyclists' Club is the most significant non-governmental organization which works on the popularization of cycling as a mode of transport. The Club builds strategic, professional partnerships with cities, local authorities and companies countrywide, while Budapest is their first and largest partner. The Hungarian Cyclists' Club worked on the preparatory works of MOL Bubi and they are still involved.
- **The Clean Air Action Group**[104]
  The organization is one of the best-known environmental NGOs in Hungary. Their activities include research, consulting, public awareness campaigns, publishing and advocacy at local, national and international levels. Besides sustainable urban and transport development, they address the topics of energy policy and protection of green areas as well.
- **Közlekedő Tömeg Egyesület**[105]
  The association posted some articles about MOL Bubi's characteristics and proposed possible measures for improvement, such as how to enlarge the system and how to attract more users. (183) (184) (185)
  They created an on-line tool which enables visual and statistical analyses of MOL Bubi usage data.[106]

The share of cycling in Budapest has significantly grown since the 2000s because of infrastructure development and the emerging and popularizing cycling movement. Compared to the 1990s the share of cycling has grown more than ten folds by 2014. (186)
Data recorded by automated bike counters show that daily maximum number of cyclists at the busiest spots could reach 5000 or even more. The average daily number of cyclists differ between 500 and 2500 throughout the city.
Cycling network development went through a boom in the 2000s and especially in the 2010s, when of the bike-sharing system was introduced as well with other infrastructural developments such as road rehabilitations, new bicycle lanes, paths and parking facilities etc. On one hand there are various good development practices, on the other hand, the bicycle network of Budapest is not complete and key elements are still missing or major road rehabilitations are needed.

[101] See the Wikipedia article: https://en.wikipedia.org/wiki/Critical_Mass_(cycling) (Cited: June 4, 2018)
[102] http://kerekparosklub.hu/ibikebudapest (Cited: June 4, 2018)
[103] http://kerekparosklub.hu/ (Cited: June 4, 2018)
[104] https://www.levego.hu (Cited: June 8, 2018)
[105] http://kozlekedotomeg.blog.hu (Cited: June 6, 2018)
[106] HolaBubi: http://kozlekedotomeg.hu/HolaBubi/ (Cited: June 6, 2018)

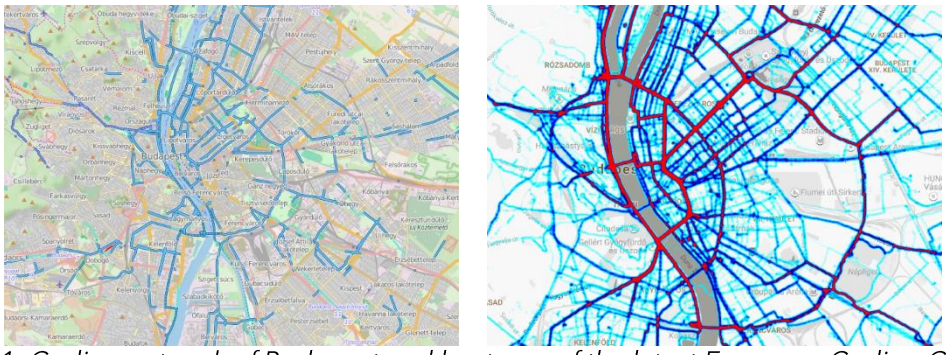

Figure 21: Cycling network of Budapest and heatmap of the latest European Cycling Challenge campaign. Although key elements are missing from the cycling network, the heatmap shows that commuters cycle in all parts of Budapest. (Sources: merretekerjek.hu[107] and cyclingchallenge.eu[108])

Figure 22: Some photos of the cycling infrastructure in Budapest
Top left – Cycle lane on a two-lane avenue
Top right – Shared-use path with markings for separation before a junction
Bottom left – Shared bus and cycle lane (Source: BKK[109])
Bottom right – One-way street with sharrows and contra-flow cycle lane (Source: BKK[110])

Although Budapest has ambitious goals and development plans to increase the share of cycling, there is no clear and strong political will which encourages the use of cycling in an exemplary manner. The SUMP of Budapest set the target, the share of cycling from 2% in 2014 must be increased to 10% by 2030 (see the figure on the next page).

[107] https://merretekerjek.hu (Cited: June 25, 2018)
[108] http://www.cyclingchallenge.eu (Cited: June 25, 2018)
[109] https://www.facebook.com/pg/bkkbudapest/photos/?tab=album&album_id=710436375681520 (Cited: July 3, 2018)
[110] https://www.facebook.com/pg/bkkbudapest/photos/?tab=album&album_id=900190540039435 (Cited: July 3, 2018)

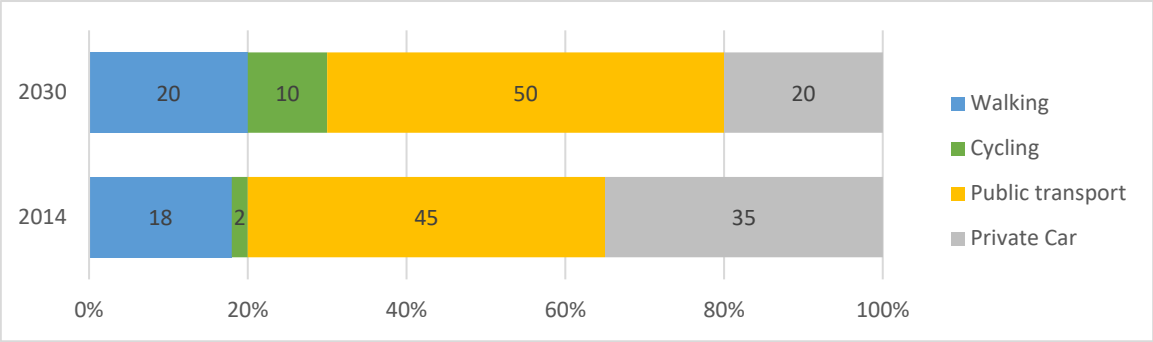

Figure 23: Modal split of Budapest in 2014 and the desired share by the SUMP for 2030 (Source of data: SUMP of Budapest (187))

7.1.2 Valencia

Valencia (originally *València*) is situated on the western part of the Mediterranean Sea, on the east coast of Spain. The city is the capital of the autonomous community of Valencia (*Comunidad Valenciana*). Valencia with its approx. 780 000 inhabitants is the third largest city in Spain after Madrid (approx. 3.15 million inhabitants and Barcelona, approx. 1.6 million inhabitants). The functional metropolitan area of Valencia is also the third largest in the country with a population of approx. 1.84 million people. There are 63 municipalities in the metropolitan area and its territory is almost 1400 km^2.
Climatic, geographical and topographical conditions of Valencia provide favorable environment for urban cycling. Valencia is almost flat which makes cycling easy in the city. Valencia has a Mediterranean climate with a mean daily temperature of 18.4 °C. The average annual precipitation is 454 mm with 44 precipitation days a year. The mean number of annual sunshine hours is approx. 2700. (188) (181)

There is a strong local civil movement is Valencia that promotes urban cycling. As far as I am informed, the most important local non-governmental organizations in the city which promote sustainable urban mobility including cycling are the following:

- **València en Bici**[111]
  The organization focuses on cycling tourism, urban cycling and mobility, and on intermodality.
- **Asociación Valenciana por el Medio Ambiente y contra el Cambio Climático**[112]
  The aim of the organization is to promote sustainable solutions to reduce the negative environmental impacts of human activity. The focus areas are climate change, energy, mobility and rodamons (network of sustainable lodges).
- **LA BICI - Biciutat Movilidad Urbana y Sostenible**[113]
  Biciutat works towards a more sustainable urban environment. Their aim is to change the status quo for humanized streets which serve people's needs.

In 2017, Valencia hosted the Iberian Congress "The Bicycle and the City" (El Congreso Ibérico "La Bicicleta y la Ciudad")[114] which is an annual event since 1996. The aim of the conference is to spread the knowledge about cycling and enhance dialogues on the topic. There is a strong political will for sustainable urban mobility and for bike-friendly developments in Valencia, the city develops progressively. However, in some cases the reactions are controversial on the political level and among citizens as well as it is normally the case for most radical change. (189)

[111] https://valenciaenbici.org (Cited: June 4, 2018)
[112] http://www.medioambienteycambioclimatico.org (Cited: June 4, 2018)
[113] http://www.biciutat.es (Cited: June 4, 2018)
[114] https://valenciaciutatamable.org/bicicleta-y-ciudad/ (Cited: June 4, 2018)

According to a survey conducted by the Spanish National Consumers and Users Organization[115] in 2017, Valencia was the second most bicycle-friendly city in Spain after Sevilla. (190)

Figure 24: Best practice – Bicifest[116] advertisement on the bikes and terminal screens of Valenbisi

About 1.9 million trips are generated within Valencia (approximately 83% of trips starts and ends in the city), while the city attracts almost 600 000 journeys from the outskirts. In 2012, 4% of all journeys were done by bike. The following figure shows the modal split of Valencia. (181)

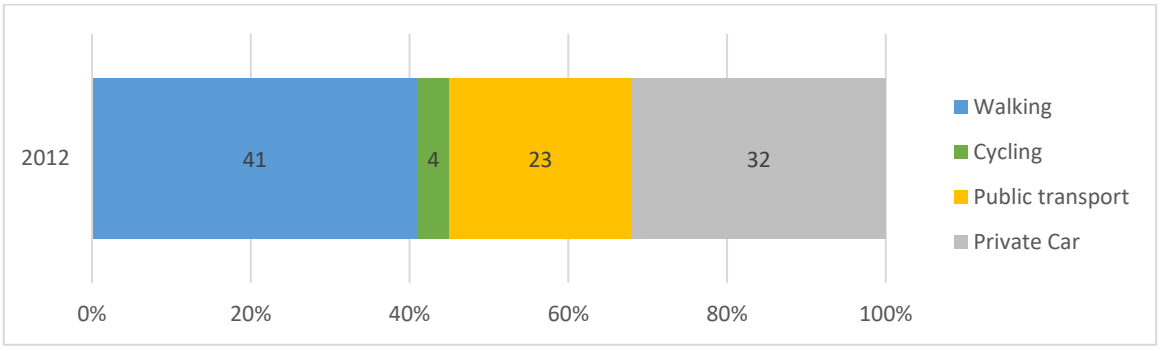

Figure 25: Modal split in Valencia, 2012 (Source of data: SUMP of Valencia (181))[117]

Cycling is quite popular in the city of Valencia and in the community as well. Quarter of the inhabitants of the community (25.8%) use bicycle at least once a week. (191) Valencia has many automatic bike counters, the data is updated and available on-line on the local governments webpage.[118] These data show that at the busiest spots the average daily number of cyclists is between 1500 and 2000, while the maximums are around 3000.
Valencia has an extensive bicycle network which connects all the neighborhoods. Although the infrastructure is not always appropriately designed, it is easy to get around the city by bike. The major roads and boulevards are mostly one-way, with at least 4-6 lanes and heavy car traffic. The most common bicycle infrastructure on these roads is two-way bike paths and separated bike lanes. The city has an extensive network of streets with 30 km/h speed limit (called *ciclocalles*), where vehicles share the road. Contraflow cycling in one-way streets or cycling in the bus lane is not allowed in Valencia.

[115] Organización de Consumidores y Usuarios (OCU), https://www.ocu.org (Cited: July 3, 2018)
[116] https://valenciaciutatamable.org/ii-bicifest-valencia/ (Cited: June 8, 2018)
[117] The SUMP of Valencia does not define an exact, desired modal share for 2030 which is the strategy's horizon.
[118] http://www.valencia.es/ayuntamiento/trafico.nsf/fCategoriaVista?ReadForm&Categoria=Sincat&Vista=vCategoriaDescargas&titulo=Descargas&lang=1&nivel=7 (Cited: June 4, 2018)

Figure 26: Typical cycling infrastructure in Valencia
Top left – Ciclocalle (cycling street) with contraflow one-way cycle path and 30 km/h speed limit
Tor right – Two-way separate cycle path on a one-way street with two lanes (car and bus lane)
Bottom left – Two-way bike path separated by a parking lane from the car lane
Bottom right – Two-way cycle path and wide sidewalk next to a four-lane avenue

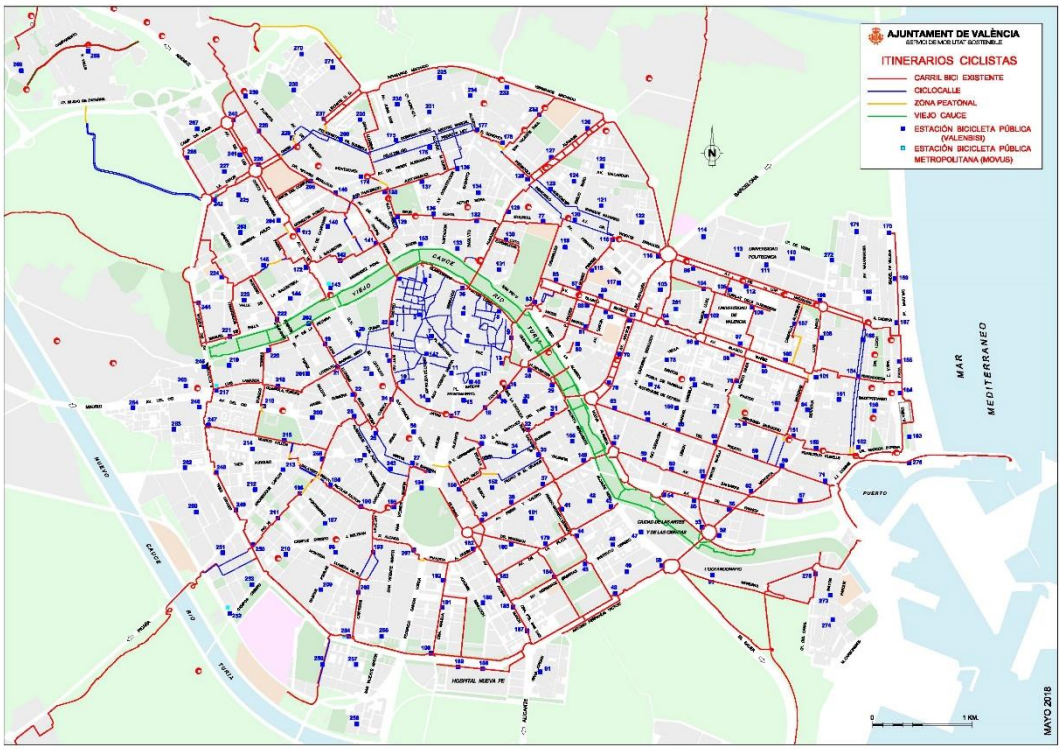

Figure 27: Cycling map of Valencia (Source: Ajuntament de València[119])

[119] http://www.valencia.es/ayuntamiento/trafico.nsf/fCategoriaVista?readForm&Vista=vCategoriaDescargas&Categoria=Sincat&titulo=Descargas&lang=1&nivel=7&expand=1&bdorigen=&idApoy (Cited: June 25, 2018)

7.2 Bike-sharing services in Budapest and Valencia

	MOL Bubi[120]	Valenbisi[121]
Launch	September 8, 2014	June 21, 2010
Implementation costs	approx. EUR 33 million	Data Not Available
Operating costs (annual)	approx. EUR 1 million	Data Not Available
Number of stations	124 (76)[122]	275
Number of slots	2 640 (1 526)	5 500
Number of bikes	1 486 (1 100)	2 750
Service area	approx. 34 km^2	approx. 46 km^2
Density of stations	approx. 3.6 stations / km^2	approx. 6 stations / km^2
Total number of active subscribers	approx. 5 000	approx. 45 000
Estimated number of trips per bike	approx. 2	6,6
Fares	Special fares are available for businesses. Available tickets and passes: 24h, 72h, 7-day, 90-day, 180-day, 365-day. Special offers combined with PT passes.[123]	Available tickets and passes: short and long-term subscription, 7-day ticket and annual pass. Special fares for combined passes with Mibisi.[124]
Annual pass	approx. EUR 38.6 (HUF 12 000)	EUR 29.21
7-day pass	approx. EUR 6.4 (HUF 2 000)	EUR 13.3
Accessibility	Phone number with PIN, smart card (valid only for MOL Bubi), smartphone application (both terminal and on-board computer access)	Personal code with PIN, smart card (Valenbisi, Mibisi or Móbilis)

Table 17: The main characteristics of MOL Bubi and Valenbisi

7.2.1 MOL Bubi (Budapest)

MOL Bubi was launched on 8 September 2014 after several years of planning and preparatory work. The scheme started its operation with 1100 bikes and 76 stations. Since then, the system was enlarged and developed, almost 1500 bikes in 124 stations can be used now.

The development was co-financed by the European Regional Development Fund and the Hungarian State. After preliminary feasibility studies and other preparatory works, the grant contract was signed on 26 August 2011. The first, estimated official launch date was 31 March 2013.[125] However, the system started operating in autumn 2014 due to several technical reasons. The present operating model should be kept for 5 years according to the

[120] http://molbubi.hu/ (Cited: June 8, 2018)
[121] http://www.valenbisi.com/ (Cited: June 8, 2018)
[122] Data at the time of launching in the brackets.
[123] More info: http://molbubi.hu/dijszabas.php
[124] More info: http://www.valenbisi.com/Subscription/Usage-fees
[125] The documents and contracts are available here: https://molbubi.bkk.hu/dokumentumok.php (Cited: June 4, 2018)

contract, which means major modifications will not be feasible until the autumn of 2019. The operations are sponsored by MOL, a Hungarian multinational oil and gas company.

MOL Bubi is a 4th generation, state-of-the-art public bike system. It has modular, portable stations with solar-powered touchscreen computer terminals. The scheme has several features. If the docking station is full and all the slots are occupied, the bikes can be locked to an extra bike stand with a built-in lock. This solution eliminates the problem of full stations as the bikes can be locked to each other as well.

Figure 28: MOL Bubi's extra electronic lock and bike stand
Left – Bike secured to the extra bike stand (Source: Mol Bubi Google+[126])
Right – Docking station with the extra stand (Source: autoszektor.hu[127])

A surveillance system was introduced for security and operation. The bikes are durable, and they are equipped with and on-board computer and GPS tracker. A smartphone application is available for easy hiring. After scanning a QR code the docking station releases the bike. There are two other ways of hiring, a dedicated MOL Bubi smart card or the user's mobile phone number and a 6-digit code can be also used to access the scheme. The hiring can be done on the bikes' on-board computer and at the terminals as well, which eliminates peak hour queues.

Mol Bubi offers short-term tickets (24h, 72h and 7-day) and long-term passes (90-day quarterly, 180-day semi-annual and 365-day annual). The following table summarizes the fares. One bike can be taken with the tickets and the deposit is approx. EUR 78.3 (HUF 25000) per bike. Four bikes can be hired in the same time with the passes.

Type of ticket / pass	24-hour ticket	72-hour ticket	7-day ticket	90-day pass	180-day pass	365-day pass
Price[128]	EUR 1.6 (HUF 500)	EUR 3.1 (HUF 1 000)	EUR 6.3 (HUF 2 000)	EUR 24.5 (HUF 7 800)	EUR 39.1 (HUF 12 500)	59.5 EUR (HUF 18 900)

Table 18: Fares of MOL Bubi

There are five key actors who share the tasks related to MOL Bubi bike-sharing scheme:

- Maintenance, logistics and rebalancing – Közbringa Kft.
- Operation, customer service, revenues - BKK Centre for Budapest Transport
- IT – T-Systems Magyarország Zrt. and Nextbike GmbH
- Marketing and communication – BKK and MOL

The service area of MOL Bubi covers the inner parts of Budapest. Therefore, there are various parts of the city where bike-sharing services are not available. As Budapest is quite

[126] https://plus.google.com/100669774186629410429/posts/iyw2mmfpz7k (Cited: June 4, 2018)
[127] http://www.autoszektor.hu/hu/content/hetfon-indul-mol-bubi (Cited: June 4, 2018)
[128] Approximate prices in EUR.

big in terms of cycling distances from the outskirts to the city center and there are some parts where the density is not sufficient for efficient operation, a bike-sharing system which operates throughout the city is not desired and would not be suitable neither. However, smaller systems around the main transit hubs and urban subcenters would be a proper solution.

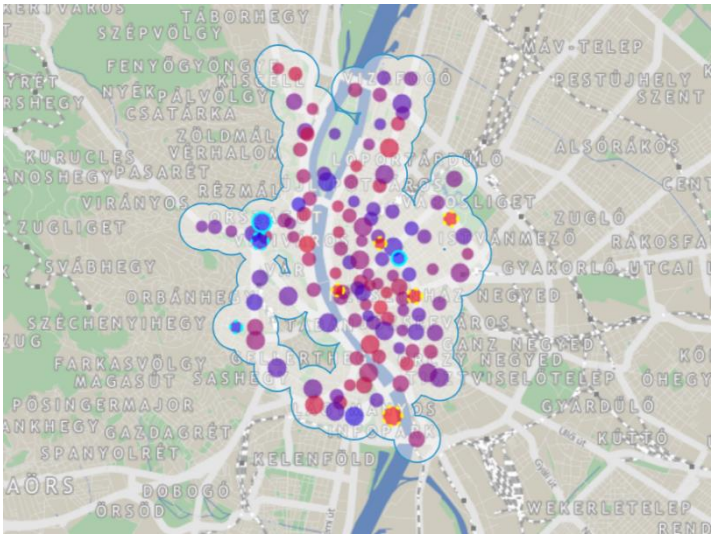

Figure 29: Stations of Mol Bubi and their catchment area (Source: Bike Share Map[129])

Various researchers and students examined different aspects of MOL Bubi such as travel pattern and big data analyses, rebalancing optimization, marketing and finance. In 2015, the Hungarian Academy of Sciences (MTA SZTAKI) and the Centre for Budapest Transport organized a data analytics challenge[130] with beneficial results both for the operators of MOL Bubi and scientists. Social equity aspects of bike-sharing availability were also examined.[131] As it was mentioned earlier, an on-line data visualization tool[132] created by a Budapest based NGO is also available.
BKK conducts various research and development projects[133] which are also connected to MOL Bubi. Flow[134] project is worth mentioning as the aim of the project was to assess the impact of walking and cycling on road congestion.

Usage data

Since the system was launched, the fares have not changed or been raised. Moreover, the promotional fares are still available. The following graph shows the trends of usage since the bike-sharing system was launched.
Data show that the number of trips is significantly decreasing. There are some known factors which might contribute to the reduction of trips like slow bicycles due to inflatable tyres or long registration procedure (for more details see the SWOT analysis below). As the exact causes are not known, MOL Bubi initiated a user survey to analyze the situation and understand the influencing factors better. The study is under preparation, the results will be available in the near future.

[129] http://bikes.oobrien.com (Cited: July 3, 2018)
[130] The MOL Bubi Challenge, https://dms.sztaki.hu/bubi/ (Cited: June 8, 2018)
[131] PAD Foundation – Bike equity, https://pad.network/projects/bike-equity/ (Cited: June 20, 2018)
[132] HolaBubi, http://kozlekedotomeg.hu/HolaBubi/ (Cited: June 20, 2018)
[133] https://bkk.hu/magunkrol/nemzetkozi_kapcsolatok/ (Cited: June 9, 2018)
[134] http://h2020-flow.eu/flow-cities/budapest/budapest-en/ (Cited: June 9, 2018)

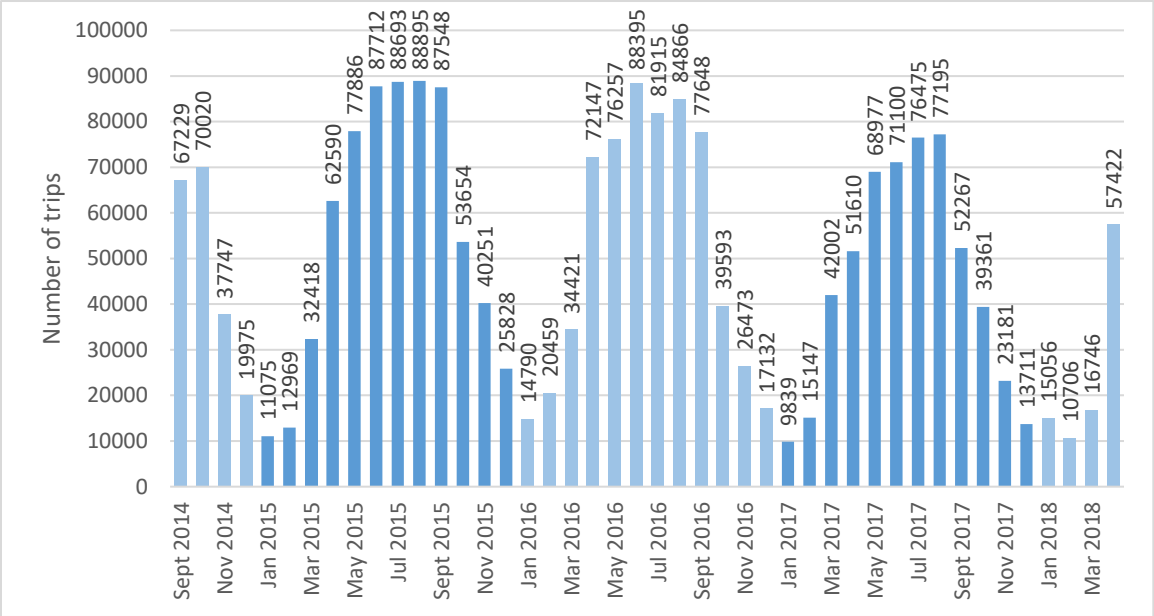

Figure 30: Number of monthly trips since the launch of MOL Bubi (Data Source: BKK)

SWOT analysis of MOL Bubi

Strengths:

- MOL Bubi has progressive features and modular technology which provide high level of flexibility in terms of hiring, returning, implementation and registration for short-term tickets. Smart bikes, GPS-tracking and geo-fencing enables real-time monitoring and provides data for efficient reallocation.
- MOL Bubi is an integral part of the transport system of Budapest. The management is part of Centre for Budapest Transport and bike-sharing services are treated as a complementary option for the city's transport offers. This approach enables integration on all levels and fosters multimodality: infrastructure development, common fare structure, signages, maps, real-time route planning and service information, customer service etc.

Figure 31: MOL Bubi has its own wayfinding signages which inform people in an exemplary manner
Left – Bike-sharing stations are shown as a possible multimodal connection on PT vehicles (Source: MOL Bubi bike-sharing system's Facebook page[135])
Right – MOL Bubi signage which informs users about the direction of the nearest station

[135] https://www.facebook.com/molbubi/photos/a.391143811038049.1073741846.255561361262962/391143884371375/?type=3&theater (Cited: June 6, 2018)

Figure 32: Good practices – MOL Bubi stations in the parking lane with direct access to road surface and cycle lane. This design eliminates the conflicts between pedestrians and cyclists while provides more space for sustainable urban mobility by reclaiming former car parking spots for cycling.

- The additional lock and the extra stand provides great flexibility as it eliminates the inconvenience of full stations. Although rebalancing has its weaknesses, MOL Bubi provides reliable services.

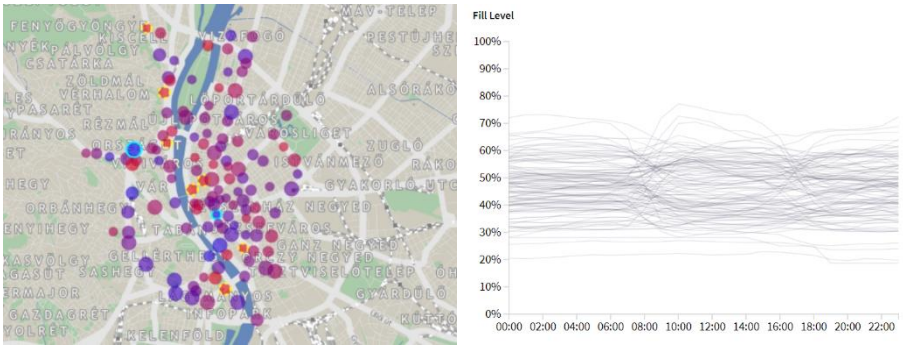

Figure 33: Reallocation of bikes
Left – Red markings show full stations and blue marking indicate empty ones. The map shows that on an average weekday morning the stations around the main attractions are full. However, the system remains balanced. (Source: Bike Share Map[136])
Right - The graph shows the average weekday fill level of MOL Bubi stations. It can be concluded that bike availability follows general travel patterns and rebalancing is effective. (Source: Bike-sharing Atlas[137])

- MOL Bubi have become a well-known brand in Hungary and even on international level. It is the biggest and most successful bike-sharing system in the country representing sustainable mobility which have become an integral part of the everyday life of Budapest.

Weaknesses:

- Small service area which covers only the inner parts of Budapest. In some parts of the city the low-density of docking stations is also a problem which should be improved.
- After almost four years of operation some of the teething problems of MOL Bubi are not solved. These problems are related to the solid tyres which slow down the bikes, there are some IT problems and the registration procedure still requires long paper work. In some cases, bureaucracy and inflexible legal environment work against the change.
- Slow, heavy bicycles due to solid rubber bicycle tyres.

[136] http://bikes.oobrien.com (Cited: June 6, 2018)
[137] http://bikesharingatlas.org/network/valenbisi (Cited: June 6, 2018)

- Complicated and lengthy registration procedure as the long-term subscriptions can be activated only in person at BKK's customer service offices.
- Some reported negative user feedbacks are available on an independent webpage called *Járókelő* [138] which allows citizens to submit complaints or urban problems. A summary about cycling related cases conclude that most of the reporters about MOL Bubi complain about dirty docking stations, insufficient rebalancing and they request more stations. (192)

Opportunities:

- Huge potential in further enlargement of the service area to cover currently not served parts of Budapest.
- New docking stations which could be funded by private investment. There are plans for developing new stations by private funding (166) and there are already three stations which were implemented following this funding model (193).
- The busiest metro line (M3) is under reconstructions for several years while cycling, especially bike-sharing could play a great supplementary role. Two new docking stations, B+R facilities and further developments were established to improve cycling conditions. This approach is fostered by several civil movements as it is a good opportunity to attract potential users. (194) (185) (195)
- Various students and researchers examined the operations of MOL Bubi and proposed actions on how to develop the system and increase its efficiency.

Threats:

- Without strong, supportive political will and financial support the enlargement and the development of the systems will not happen.
- Bicycle-friendly urban environment is an important basic condition which is partly missing. The conditions are not everywhere favorable for users, especially for those who are not experienced cyclists. Infrastructural developments are needed which also requires political and financial support.
- Although MOL Bubi has a modular, flexible station design, the implementation still requires planning and authorization procedure. Even if the funding for the expansion of the system is available, some of the districts of Budapest hinders the development. The lack of free public spaces limits the expansion and converting parking spots to docking stations could be an efficient and win-win solution. However, some local governments, the owners of the public spaces, do not want to provide their parking spots for the docking stations for made-up reasons. As it was mentioned before, although the SUMP of Budapest clearly defines that the modal share of cycling should be increased while car use should be decreased, banning on-street parking and providing more space for cycling remains a taboo and decision makers still insist on the parking spots.
- After the initial growth the number of users and journeys does not meet the previous expectations which were stated in the grant contract. Moreover, the number of monthly trips is decreasing. (196) (183)

[138] http://jarokelok.blog.hu (Cited: June 6, 2018)

7.2.2 Valenbisi (Valencia)

Valenbisi is a public bike-sharing system promoted by the city council of Valencia and operated by JCDecaux which launched similar systems around Europe (e.g. Vélib' in Paris and Dublinbikes in Dublin) and in other Spanish cities (e.g. Sevici in Sevilla and TusBic in Santander) as well. One year after the official governmental decision in 2009, Valenbisi was introduced in 2010. The planning and implementation procedure took only one year. (197) Valenbisi has been operating since 21st June 2010. The service is available 24 hours a day, throughout the year with 275 stations and 2750 bicycles. As the map below shows Valenbisi serves the whole city.

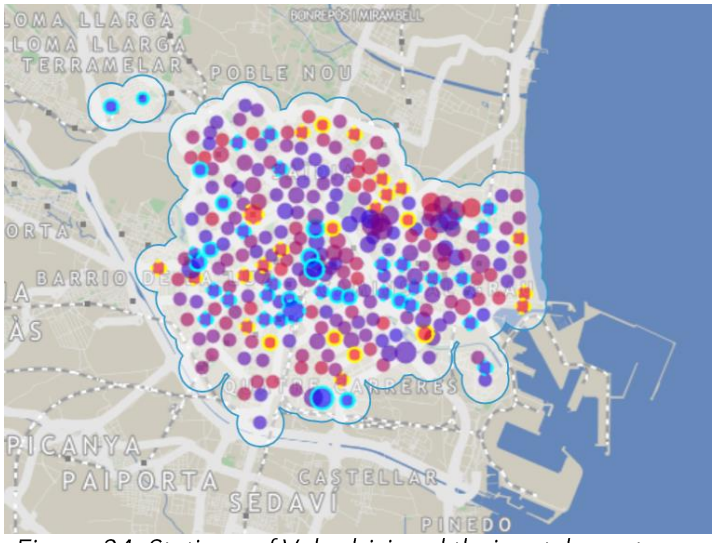

Figure 34: Stations of Valenbisi and their catchment area (Source: Bike Share Map[139])

Valenbisi was launched in exchange for outdoor advertising and street furniture in the city as it is the general business model of Cyclocity[140] of JCDecaux. The long-term agreement with its strict conditions was signed in 2009 and is valid until 2029.

During the interviews I conducted I had the impression that the agreement is not completely beneficial for the city. Even if the city does not have to pay for the services directly, it compensates for them with free advertising. It is estimated that the annual operating cost is around € 2200 + IVA per bike. Changing the conditions of the agreement is not easy, and in some cases, it would cost a lot to the city. For example, the rebalancing of the bikes is not sufficient, it is easy to find empty or full stations all day. To make the reallocation more efficient by adding extra vehicles and capacity, the costs of the improvement should be covered by the city. If extra stations and bikes are needed, the cost should be covered by the city as well.
Valenbisi is considered as a great opportunity to provide the possibility of cycling to all. However, the city would like to emphasize the use of private bikes rather than improving the bike-sharing services as it could cost more due to the already mentioned strict agreement with the operator. The aim is to focus on intermodality and on the integration with MiBiSi.

A master thesis from 2016 focuses on user satisfaction among Valenbisi costumers (who have access to the system and use or used to use the system). A questionnaire was carried

[139] http://bikes.oobrien.com (Cited: July 3, 2018)
[140] Cyclocity, http://en.cyclocity.com/ (June 8, 2018)
More info: https://en.wikipedia.org/wiki/JCDecaux#Bicycle_rental_systems (Cited: June 8, 2018)

out in August 2016. (198) The main findings of the author, Elena Cantir, the results of her analysis and some facts about the methodology are as follows.
Methodology:

- Sample: 100 users, representing Valenbisi users.
- The respondents were chosen personally at Valenbisi stations. The link of the on-line questionnaire was handed over by the interviewers. The respondents filled out the survey individually through an on-line platform.

Main findings which are important and relevant for this thesis:

- Facts about former users:
  - To the question of *"What is the main reason for you have stopped using Valenbisi?"*, 25% of the answers reflected on dissatisfaction regarding conditions or location of stations (bad conditions, full or empty stations, density etc.).
    A bit more than a quarter of former users bought their own bicycles and used it regularly instead of Valenbisi which could be considered as a great success.
  - Among the users who used to use Valenbisi and answered that they would not plan to use it again the main obstacles were the following: users preferred to use their own bikes (approx. 25%), the stations were too far (5%), the bikes were not appropriate for daily use (approx. 27%).
- Assessment of Valenbisi by regular users (who are mostly satisfied with the services or do not have other options e.g. who do not have bike):
  - 87.5% of regular users were very or mostly satisfied with the services
  - Most of the users were satisfied with the location of the stations but almost 15% of them were not.
  - Almost 93% of regular users would have recommended Valenbisi to others which represented broad satisfaction.
- People would have used Valenbisi more if the following circumstances have been developed:
  - More bicycle-friendly infrastructure and road design (23% of respondents)
  - More comfortable and less heavy bikes (36.5%)
  - Lower fares (34.5%)
  - More stations (40.6%)
  - Better availability of bikes: more bikes and docks to avoid full and empty stations (49%)
- Satisfaction of customer service:
  - 26% of the users were not or mostly not satisfied with the customer service of Valenbisi.

The main recommendations of Elena Cantir to improve the services of Valenbisi:

- Increase the number of stations
- Enlarge the stations by adding more slots
- Reduce the age limit for subscription to 16 years
- Introduce new ways of payment
- Introduce toll-free call center
- Open new, easily accessible costumer service office
- Provide better, more comfortable bikes
- Offer bonuses (e.g. bonus for bringing bikes to empty stations)
- Introduce a booking system for bikes or slots
- Light signal for confirmation of successful return

MiBiSiValencia[141]

The metropolitan area of Valencia is covered by MiBiSi, which is a bike-sharing system operated by MOVUS, a Paterna based SME. The services of MiBiSiValencia are available in ten towns around Valencia (Catarroja, Torrent, Paterna, Mislata, Aldaia, Quart de Poblet, Xirivella, Alaquas, Burjassot and Alboraya). In total, MiBiSiValencia has 114 stations and more than 1200 bicycles. During the last 3 years more than 600 000 journeys were made by approx. 10 000 users.
Since September of 2017 MiBiSiValencia and Valenbisi offer "semi-integrated" services. There are six stations work as "interchange" or "transfer" stations where users can change bikes of the two systems and other four stations will be established soon. A combined ticket with reduced fares is also available to attract more users.
The mentioned six interchange stations are the following: Mediamarkt de Campanar, Nuevo Centro, Rectorate of UPV, Sant Isidre, Complejo 9 d'octubre and Cruz Cubierta. (199)

Figure 35: Stations of MiBiSi (Source: mibisivalencia.es[142]*)*

In Valencia a kind of multi-operator bike-sharing model exists as the services of Valenbisi and MiBiSi are connected. However, further actions and developments with interoperable solutions are needed to fully integrate the two systems.

Some interesting facts about Valenbisi and Mibisi:

- The services of Valenbisi are accessible with a smartphone application using NFC technology (Mobilis NFC app.[143])
- The users of TorrentBus (municipal bus operator) can use the TorrentBici (local public bike-sharing system) (200)

Usage data

Valenbisi reached its annual record with 112 290 subscribers in 2012. However, since 2013 the number of users has been decreasing continuously. Currently and according to the latest public figure the number of active subscribers is 45 026. In the last three years Valenbisi has lost 50% of its users. (201)

[141] More information here: http://www.mibisivalencia.es (Cited: June 5, 2018)
[142] http://www.mibisivalencia.es/mapa/mapa.php (Cited: July 3, 2018)
[143] https://play.google.com/store/apps/details?id=com.transermobile.eige&hl=es (Cited: April 23, 2018)

There are several reasons why the number of subscribers has decreased:

- Former users started to use their own bicycles because it is more convenient. (198) 52.4% of former users of Valenbisi changed to private bike. (202)
  While the number of Valenbisi users is decreasing, the use of private bike is increasing significantly. This happens for several reasons but one of them might be that bike-sharing in general functions as a "gateway drug" which means after new users try bike-sharing they realize that cycling is a convenient mobility option. After a while people might take one step further and change to private bicycle because in some cases it could be more flexible or comfortable. In conclusion, Valenbisi can be considered as a success for sure.
- Since 2013 the fares increased. When the system was established in 2010 the annual subscription cost EUR 18. In 2013 the fare increased to EUR 26.07 and it was the first year when the number of users decreased. In 2014 the price cost EUR 27.12 and since 2015 the annual subscription has been EUR 29.21. Although the prices and the number of users are correlated, without in-depth analysis conclusions should not be drawn.

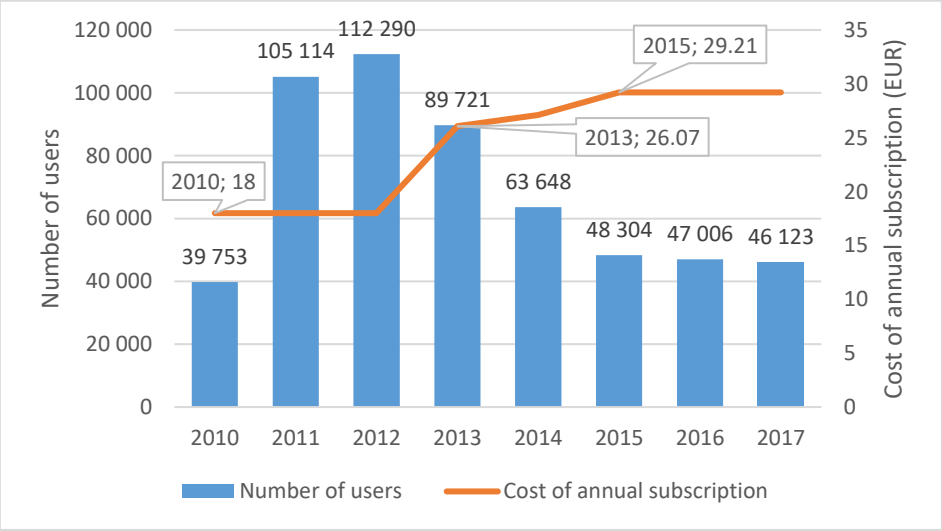

Figure 36: Number of users and annual fare of Valenbisi since its establishment (Various on-line sources[144])

It would have been interesting to analyze the number of short and long-term subscribers as well as to examine how the numbers of the two types of users have changed. I wanted to carry out the analysis, but I have not received the requested detailed travel and usage data from the operator by the time I had to finalize the thesis.

[144] https://www.20minutos.es/noticia/2751620/0/valenbisi/usuarios/valencia/ (Cited: April 20, 2018)
http://valenciaextra.com/es/aumentan-usuarios-bici-privada/ (Cited: April 20, 2018)
http://www.lasprovincias.es/valencia-ciudad/usuarios-valenbisi-estancan-20171003003736-ntvo.html (Cited: April 20, 2018)

SWOT analysis of Valenbisi

Strengths:

- Valenbisi covers most of Valencia and it is easy to find docking stations throughout the city as the system operates with a high number of bicycles and stations.
- Affordable, low fares compared to the local average wage.
- Cyclocity scheme, the technical equipment of Valenbisi provided by JCDecaux, is a reliable, widespread technology which functions relatively stable in Valencia and in almost 30 other cities.

Weaknesses:

- One of the main weaknesses of Valenbisi is that the system cannot serve the users' demand in peak hours due to insufficient reallocation of bikes. During the morning, stations in residential areas go empty while around the main attractions stations become full. In the afternoon peak hours, the same happens but in the opposite direction. Bike availability and system reliability both are key criteria for success, otherwise people will not use it. (203)
  However, there are some smartphone applications which provide information about available bikes and slots. In addition to providing information more efficient solutions should be implemented and reallocation procedures should be improved.

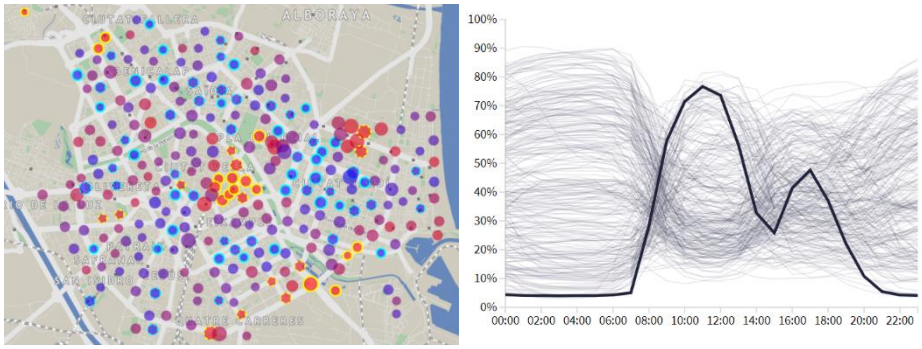

Figure 37: Insufficient reallocation of bikes
Left – Red markings show full stations and blue marking indicate empty ones. The map shows that on an average week day morning all the stations are (almost) full around educational institutions and workplaces while the stations are empty in residential areas.
(Source: Bike Share Map[145])
Right - The graph shows the average weekday fill level of Valenbisi stations (UPV Caminos is highlighted). It can be concluded that bike availability follows general travel patterns as the bikes are rarely redistributed. Stations at tourist destinations has similar patterns.
(Source: Bike-sharing Atlas[146])

- The services of Valenbisi and Mibisi are not fully integrated, the users should change bikes at defined interchange stations. That makes the trips from the metropolitan area to Valencia by public bike more complicated and less attractive. Further measures are necessary.

Opportunities:

- Healthy lifestyle and active mobility is popular in Valencia which offers the opportunity to attract potential users.
- Bike-sharing could be an attractive alternative once all the necessary measures which foster better integration would be implemented.

[145] http://bikes.oobrien.com (Cited: June 6, 2018)
[146] http://bikesharingatlas.org/network/valenbisi (Cited: June 6, 2018)

- Various researchers and students analyzed the services of Valenbisi. The proposed recommendations could provide valuable inputs for future developments. Besides that, Valenbisi and its system performance are an integral part of the city's transport model.

Threats:

- The agreement between the city and the operator is relatively strict. Although the operations in some cases are not sufficient, it seems strong political will is lacking for the change as all the desired developments have cost impacts.
- The emerging trend of private bikes among former Valenbisi users is an excellent phenomenon while it also threatens its services as the number of new users has significantly decreased in the recent years.

7.3 Dockless bike-sharing systems in Budapest and Valencia

This sub-chapter summarizes the status quo regarding dockless bike-sharing services in the two cities.

7.3.1 Budapest

There is a dockless bike-sharing operator in Budapest. Donkey Republic[147] originally offered ride and return services for tourists. However, since autumn 2017, they offer special membership plan for frequent users as well. Regular users should pay a membership fee of HUF 4 000 a month and the first 30 mins are included. The bikes can be picked up from any of the hubs and should be dropped off at a designated hub (one-way trips are allowed). Moreover, Donkey Republic has special offers for those who use their bikes during the reconstructions of M3 metro line. Unfortunately, usage data is not available.

In addition, Budapest received various proposals from dockless bike-sharing operators and conducted a cooperation agreement with one of the largest market actors as well.
Although the dockless bike-sharing boom already reached Budapest, a comprehensive professional discourse has not started yet. Dockless bike-sharing systems are not the subject of political or decision-making debates either. To conclude, Budapest follows a wait and see approach regarding regulating dockless bike-sharing operators.

7.3.2 Valencia

Dockless bike-sharing services are currently not available in Valencia.
In 2017 OfoBike and other dockless bike-sharing operators offered their services to the local government of Valencia but the offers were refused by the city. The official reasons why Valencia did not want to give permission was to avoid unfair competition between operators and prevent all the negative effects related to dockless bikes such as careless user behavior or occupation of public spaces. Another important issue why the city refused dockless bikes is that the operators may have posed a threat to local bike rental businesses. (204)

[147] https://www.donkey.bike/hu/v%C3%A1rosok/kerekpar-kolcsonzes-budapest/
(Cited: June 21, 2018)

7.4 Recommendations

Developing scenarios is a common practice in strategic planning such as elaborating sustainable urban mobility plans (SUMP). Developing alternatives for the future helps planners and decision makers to understand better the effects of the proposed measures. Moreover, scenarios allow discussion about the possibilities and support decision-making. I chose this method, to develop scenarios, to present my recommendations in a systematic way. I adapted the EU's SUMP guideline's recommendations and I developed the following scenarios (13):

- Business-as-usual scenario, which describes the development assuming that there will be no significant changes in the technology and the already programmed actions will be done.
- Different alternative scenarios for future development, based on the previously described dockless technology, its limitations and necessary supplementary activities.

The impacts of the proposed scenarios are estimated in a simple, quantitative way. Further planning and a thorough assessment is necessary to understand the exact impacts of the proposed measures and the investment and operating costs.

The first step in both cities should be a detailed user-need assessment, which provides the basic requirements for future development. Moreover, the base values are essential for future monitoring and the performance of the bike-sharing services and user satisfaction will be compared to the base values as well.
The sample of the analysis should represent the potential and actual users of bike-sharing services. Several on-line and personal tools are available for data collection and interviews. This thesis already mentioned some good practices, a user questionnaire about Valenbisi (198), BiciMAD (56) and MOL Bubi (38), and there are various other good examples as well (205). The user questionnaire should cover at least the following topics:

- User experience and satisfaction: likes, dislikes and desires
- User profile: who (would) use the scheme (demographic data), for what purposes
- Mobility habits: preferred and used transport modes, daily mobility habits, cycling habits, frequent destinations etc.
- Cycling conditions
- Bike-sharing and cycling attitude in general and regarding technology aspects
- Pricing

Personal user interviews, in-depth analyses, stakeholder and expert interviews could be useful and necessary as well.

Appropriate preparation is essential for successful operation and high level of user satisfaction. Therefore, this first step should not be omitted. Low levels of user satisfaction or usage due to inappropriate preparatory work do not necessarily mean that a well-planned bike-sharing scheme would not be popular.

Besides monitoring user needs, a complex, coordinated approach among all relevant key stakeholders, as it was described in chapter No. 4.2, is needed in both cities and the planning and discussion should cover at least the topics as follows:

- Promoting cycling and bike-sharing for everyone
- Dense and continuous network of high quality and attractive cycling infrastructure
- Better conditions to support intermodality and integration with public transport both on physical and administrative level (e.g. MaaS)

7.4.1 Budapest

Based on the analyses of dockless technology, mobility situation and the bike-sharing services in Budapest, I proposed the following scenarios for future development.

1. **Business-as-usual scenario**

This scenario assumes that MOL Bubi and its technology will remain the same and the already decided improvements will be done. The planned expansion of the service area will be completed. The system and its elements will be improved to address their weaknesses and the operation will be optimized constantly as well.
The agreement between the operator and the city is valid until November 2019 and it will likely be extended for one more year. It means that the technology, the operating model will not change until November 2020 and Budapest has more than two years to prepare for the change.
As it was mentioned, an optional financial framework is available to enlarge the system and improve the density in the existing service area up to 225 docking stations in total.
The improvement of MOL Bubi with the application of electrical bicycles pop up in the news time to time but there is no strong political will or professional discourse about that. Although the e-bikes could improve the accessibility of the bike-sharing system in the hilly parts of Budapest, other improvements would provide better value for the same amount of investment.

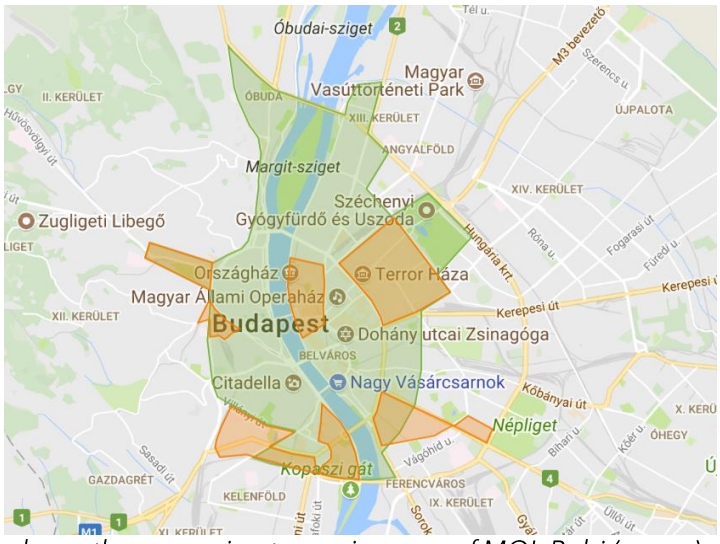

Figure 38: The map shows the approximate service area of MOL Bubi (green) and the zones where the density of the stations should be improved (orange) (Based on (184))

It is expected that the system accessibility will increase as the density of the stations will be greater. Besides station development, additional measures are necessary to improve the weaknesses of MOL Bubi and attract new users. To identify these additional measures, the mentioned user satisfactory survey, which is under preparation, could solve as a base for further planning and to identify the hidden weaknesses. According to the analysis I made, at least the slow and heavy solid tyres should be replaced, and the registration procedure should be simplified as well as the other known teething problems of the system should be solved.

2. **Developing and enlarging the existing bike-sharing scheme without the involvement of further market actors**

This scenario assumes that besides the already decided and planned developments MOL Bubi will be further developed and enlarged. The bike-sharing system will operate with the same technology and operating model without the (official) involvement of any other actors or dockless bike-sharing providers.
Nevertheless, it cannot be excluded that dockless bike-sharing operators will hit the streets of Budapest, even if the city will not initiate official agreements with the operators. It is entirely possible as it happened in other cities and as it happens now in the case of Donkey Republic. The 3. scenario refers to this case.

Budapest 2030 strategy defines the desired urban structure of Budapest and proposes a hierarchy for urban centers (see the figure one the next page). (206)
A major difficulty in the case of this scenario is that at these sub-centers and intermodal stops most people travel in one direction in the morning and in the other direction in the afternoon, so rebalancing the system could be challenging or even impossible. The idea is that around these sub-centers the bike-sharing system could operate isolated from the system which operates in the city center without any direct connections. However, these smaller sub-systems would be integral and interoperable parts of MOL Bubi. This scenario recommends that the technology and operating model remain the same.
As most of the trips are made in one direction, further studies are needed on user demand and travel patterns analysis. The conclusions could be drawn by estimating the number of needed bicycles and needed amount of space for the docking stations. MOL Bubi stations should be implemented around those sub-centers where a bike-sharing system could be a feasible and suitable option regarding user demand and operation aspects.

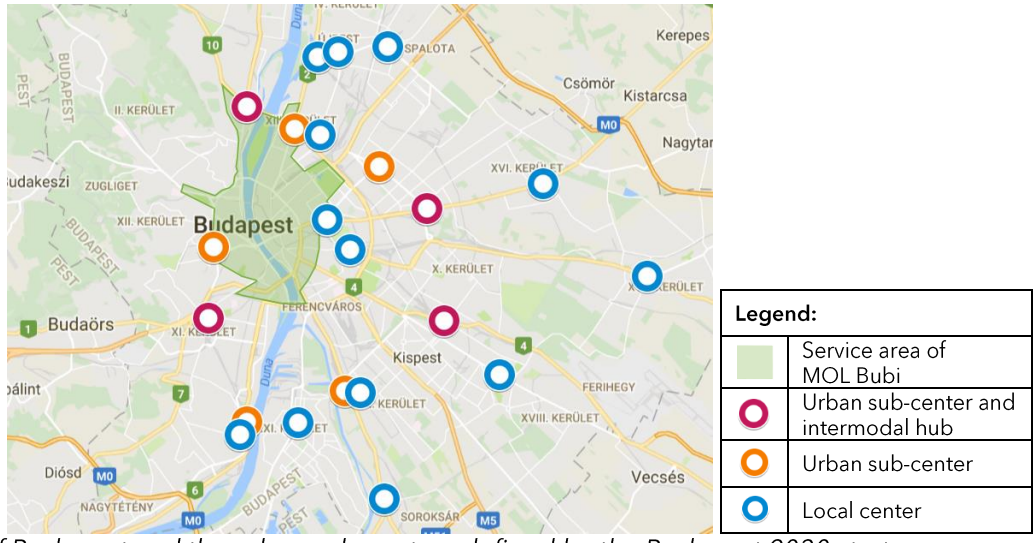

Figure 39: Map of Budapest and the urban sub-centers defined by the Budapest 2030 strategy

After the involvement of new parts of Budapest, it could be estimated that more people will tend to use the bike-sharing system which could encourage cycling for local trips or as part of an intermodal mobility chain.

3. Complementing MOL Bubi by new dockless bike-sharing operators

This scenario assumes that further dockless bike-sharing provider(s) will offer large-scale services in Budapest.[148] It is assumed that dockless bikes could complement the existing bike-sharing services regarding its density and its service area while the technology and operation of MOL Bubi remains the same.
Dockless bikes could increase the accessibility of bike-sharing services by complementing MOL Bubi where the density of the stations is lower. The hubs of dockless bikes, as semi-dockless station design is recommended, could be smaller than the MOL Bubi docking stations, therefore the implementation could be more flexible in those parts of the city where decision makers and the reallocation of public space does not prioritize cycling. Although the dockless bicycles might not occupy less space in total, the hubs could be smaller by accommodating less bikes in one place than a general docking station.
Dockless bikes could be a suitable option out of the present service area of MOL Bubi as well. In less dense parts of Budapest dockless bikes could enlarge the service area of bike-sharing in a more efficient way. Dockless bikes could be a suitable solution in that case as well, especially around the sub-centers which were described in the previous scenario.

As it was discussed earlier in the thesis, proper regulations or agreement(s) with the future operator(s) are essential. During the preparatory works, the operators and the city of Budapest should work together to coordinate and integrate the different services into a common platform. There are some additional recommendations and aspects for future development:

- The bikes of MOL Bubi are equipped with an extra lock which provides the possibility to lock the bicycle to a simple bicycle stand if all the slots are occupied. Although the bikes can communicate only with the kiosk of the docking station, changing the communication module could provide the possibility of dockless operation. In that case MOL Bubi could operate in a more flexible way without additional market actors.[149] Additional hubs with bike stands could be easily added to the system, especially in less dense areas. Meanwhile, in more dense parts of the city, docking stations which ensure that the bikes are parked orderly could remain. Further analysis is necessary to examine whether this kind of technical modification would be a cost-effective solution.
- MOL Bubi, its image and its green color have become well-known and an integral part of the everyday life of Budapest. The brand and the image might be kept as it attracts a lot of people.
- Proper regulations and preparatory work are essential as it can be concluded by various international examples. In the case of Budapest, this issue should be emphasized as well. Especially in the light of recent happenings, when Uber entered the market and Budapest experienced the drawbacks of insufficient, inflexible regulations. After several months of debates and demonstrations, Uber was banned. Although the business model of Uber could be argued, the chaos generated by the bureaucracy and the lobby groups of the taxi industry distracted the attention from the main principles. Uber highlighted a market niche and provided a more reliable service, but it was banned without taking the advantages of the opportunity. This mistake cannot be repeated with dockless bikes.
- As Budapest has ambitious goals to increase the share of cycling and other sustainable modes by decreasing the share of car use, public space occupation of different modes of transport should be reviewed. Street space and parking lanes

[148] Although Donkey Republic offers a small-scale system with dockless bikes, which focuses more on tourists and on occasional users.
[149] Like Social Bicycles in the US. http://socialbicycles.com/ (Cited: July 1, 2018)

occupied by cars should be reclaimed to provide more space and more favorable conditions for cycling and for people. Therefore, to avoid the inequalities of public space, some form of recommendation or regulation should be implemented to provide a standard for public space distribution.[150]
This step is strongly recommended as some of the districts of Budapest have already started to ban new forms of mobility and refuse to provide public space for bike-sharing. (207) (208) (209)

As dockless bikes could increase the accessibility of bike-sharing services, it is estimated that the number of users would grow as well. Dockless bikes could strengthen the weaknesses of MOL Bubi, which might attract new users, especially in the new parts of the service area.

7.4.2 Valencia

Based on the analyses of dockless technology, mobility situation and the bike-sharing services in Valencia, I proposed the following scenarios for future development.

1. **Business-as-usual scenario**

This scenario assumes that only the already decided projects will be done and no further actions will be taken. As it was already mentioned, cycling conditions are developing in Valencia and there are various projects for the future. However, as I am informed, the only major planned development related to the bike-sharing services is the further integration of MiBiSi and Valenbisi by implementing more interchange stations to enhance intermodality. There are no planned greater developments related to the rebalancing problems, nor to system enlargement.

Figure 40: The map shows the service area of Valenbisi (green) and the six interchange stations of BiBiSi (blue)

The number of users has significantly dropped in the last years. Although the volume of usage has been stagnating recently and even a small growth can be seen, it is estimated that without serious actions the number of users will not grow.

[150] A good example is the approach of Barcelona which is discussed in chapter No. 5.4.1.

2. Improving the services of Valenbisi and keeping the present operating model

This scenario assumes besides the already planned developments further actions will be done to improve the services of Valenbisi by eliminating the weaknesses of the system.
The recommended improvements which should be implemented are as follows. As the agreement between the city of Valencia and the operator is valid until 2029 and the city does not have direct control on the development of the system, some of the proposed measures might seem unrealistic but I mention them as they could be efficient solutions. To apply the proposed measures, it is recommended to review and change the conditions of the agreement, as far as possible.

- Probably the greatest problem is insufficient rebalancing. System reliability is a key condition to attract users. To solve these problems, I recommend the following solutions. The improvement and optimization of the rebalancing processes are necessary by increasing the capacity of the staff who relocates the bicycles and by applying new, more efficient rebalancing methods. Adding extra slots or stations near the overloaded docking stations could be a short-term solution. Updating the system with a similar technology like MOL Bubi's extra locks and bike stands which provide the possibility to extend the capacity of the docking stations when all the slots are occupied would be a good but a less realistic solution.[151]
  As the demand for Valenbisi is higher in the city center and around universities, another solution could be providing long term bike rental services for university students. In this case students could be encouraged to use bicycle as well.
  It can be concluded that it is not easy to solve the large scale, one-way user demand without dramatically increasing the capacity for rebalancing.
- In some cases, station placement should be improved as well. There are stations which do not have direct or barrier free access to the cycling path or to the street. This design forces the users to cycle on the sidewalk which should be eliminated. Therefore, these stations should be reviewed and moved to a better location. Some good practices for docking station placement were already introduced.[152]

Figure 41: Good practice: Valenbisi station placement
The bicycles are directly accessible from the bike-path. However, it would be better if the bikes on the right were placed in the opposite direction.

[151] The bike-sharing system of Helsinki has a similar feature.
https://kaupunkipyorat.hsl.fi/en (Cited: July 3, 2018)
[152] For further good examples see NACTO's Bike Share Station Design Guide.
https://nacto.org/publication/bike-share-station-siting-guide/ (Cited: July 3, 2018)

Figure 42: Hardly accessible Valenbisi stations
Left - The station is placed between the sidewalk and a taxi stand and bounded with curbs
Right – This station is accessible only from the sidewalk as there is no accessible curb to the street

- Sometimes, especially at busy stations users have to queue and wait for their turn as the hiring process is quite long and there is only one way to hire the bicycle. Besides that, even long-term users have to accept the same conditions in all cases. Therefore, the hiring process should be simplified by decreasing the steps and the needed amount of time for hiring. Adding new hiring methods like onboard computers with smart card readers might be a good but an unrealistic solution.
- To enhance intermodal trips by the integration of the public transport services and bike-sharing services, the information and public transport route maps should be updated and signages should be added to provide information on the nearest docking station. The information system of MOL Bubi could be a good example.

3. Improving the bike-sharing services in Valencia with dockless technology

This scenario assumes that the services of Valenbisi will remain and it will be complemented with dockless shared bicycles. However, it is a less likely to happen scenario because the city of Valencia refuses dockless technology, as it turned out during the analysis of the current situation.
Despite the above circumstances, it would be worthwhile analyzing and assessing the impacts of dockless bikes in Valencia. The capacities and insufficient rebalancing of Valenbisi do not meet the user demand in several parts of the city. To attract more people to use bike-sharing, a test phase of dockless bikes would be a suitable option to find out whether this solution could be a sustainable complementary option. There is a significant demand for bike-sharing among university students as it can be concluded by the available usage data. A test phase of dockless bikes as a complementary service around the university campuses and the residential areas where most of the students live would be a good opportunity. Another target group could be commuters. As the metropolitan area is less dense while the distances to the city are favorable for cycling, dockless bikes could be a good solution as well.
By providing more flexible and reliable bike-sharing services, the number of users might grow again.

8 Conclusion and future work

This thesis highlighted the fact that bike-sharing services could play a great role in mitigating the consequences of mass motorization and the mobility problems of our cities. Proper preparatory works and planning, which address the challenges of the implementation could ensure successful operation and user satisfaction.
Bike-sharing has become a standard tool in cities and has revolutionized urban cycling in various cities around the world when new generation dockless, free-floating bike-sharing services hit the market. Although these systems have some disadvantages compared to station-based technology, they provide great flexibility for users and for large-scale development as well. There are some teething problems, but the benefits outweigh the possible drawbacks which otherwise can be avoided by proper regulations and other actions. To combine the advantages of station-based and dockless technologies, a framework for a multi-operator model was also discussed.
Despite its wide range of benefits, dockless bike-sharing is not a solution which fits all cities. The case studies showed that dockless bikes can complement the existing station-based services, especially in those areas where the stations are less densely located. However, there could be several conditions which limit the application of dockless bicycles such as already existing, dense network of stations and political or administrative barriers.
It can be concluded that new generation dockless bike-sharing services pose new challenges for cities but there are several tools which help decision makers and professionals to implement a beneficial dockless bike-sharing scheme. The key issue is to have a clear desired future and mobility system and all the decisions should follow the defined vision. A comprehensive regulation for public space allocation for different kind of transport modes could be an effective tool in various dense cities as well where reclaiming city streets for people is a certain taboo.

Future work

I am interested in sustainable mobility and urban planning and I have enthusiasm for improving the mobility system and cycling conditions in Budapest. Therefore, I decided to continue my research and work on the case of Budapest and other Hungarian cities. I want to enhance and broaden the debate on dockless bike-sharing services and their possible applications. I also want to analyze the proposed scenarios for Budapest and examine the impacts of each to define detailed and achievable measures to improve the bike-sharing services of Budapest. Besides that, I would like to extend the research to other Hungarian cities to examine the opportunities of dockless bikes.

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Photos without references are photos of the author all the other photos with references come from external sources.

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