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Evaluation-Method for a station based Urban-Pedelec Sharing System

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Abstract

In the context of a national research project in the field of electric mobility, the University of the Federal Armed Forces in Munich, managed by the department of traffic engineering, cooperates with the German Railway Network (DB) to integrate pedal electrical bicycles (Pedelecs) into the existing scheme of the public bike sharing system in Munich, known as Call a Bike. The primary objectives investigated within this study are to find a strategy for a model-based distribution of charging-stations, to implement docking-stations and electric bicycles, and to analyze the mobility patterns of possible customers. A model to simulate bike traffic and the special needs for electrical bikes will be developed as well.

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Keywords: Bike Sharing; Pedelecs; Station-based Evaluation

1. Rise of Public Bike Sharing Systems

A new buzz word is spreading: Share-Economy or Shareconomy describes a trend in metropolitan regions to share goods and things that one does not necessarily need to possess, but just can use. In the field of mobility and transport there are two typical examples: Car Sharing and Bike Sharing Schemes. So far there is almost no major city on the globe, especially in the industrialized countries, that is not implementing, or at least thinking of public sharing systems, like Bikesharing or Carsharing, to present a solution to the threatening danger of traffic gridlock.

A growing number of large cities, especially in Europe, North America, and Asia, offer public bike systems, making an important contribution to promote cycling as an innovative, environmentally friendly and energy efficient form of mobility. In some cities bike sharing is used as a starting point for radical changes in urban and transport planning. The number of cities with bike sharing systems increased from 68 in 2007 to over 675 by the end of 2013. As a result,

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around 700.000 bikes, distributed at 33.000 stations, currently float through cities around the world. The number of cities with new, registered bike sharing systems increased by 60% from 95 in 2012 to 152 in 2013. The vast majority of new bike sharing systems were implemented in China, North America and Europe (Demaio, Meddin 2013).

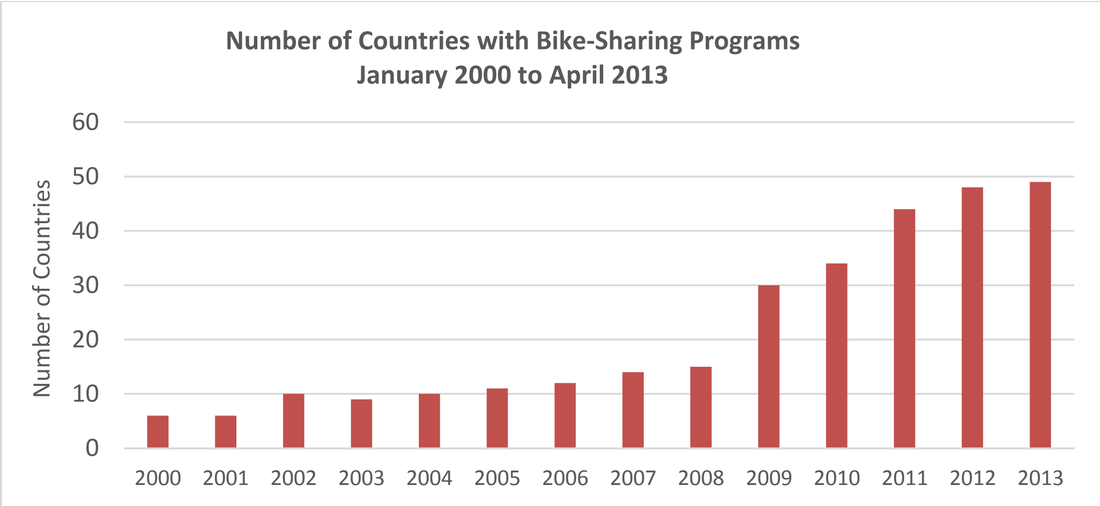


Figure 1: Number of Countries with Bike-Sharing Programs (Earth Policy Institute 2013)

Particularly cities with low modal-share of cycling and low ownership of private bikes benefit from new bike sharing systems. In major cities like London, Paris or New York bike sharing was implemented within the last years to facilitate a shift from motorized traffic to the bike. In addition, bike sharing schemes are an indicator for bike friendly transport policies and stimulate, in combination with public transportation services, the willingness of the inhabitants to use eco-friendly means of transport.

New York City illustrates that even an extremely dense and car dominated city can implement a bike sharing offer to complement the public transport system and provide a fast mobility option for short trips within the city. More than 50 million tourists are an important target group as potential users as well. Two years prior to the public opening of the bike sharing scheme in 2013, the best locations for bike stations were found in a large civic participation process. Currently there are approximately 4,000 bikes in 275 stations available. The goal is to expand the system up to 600 stations with 10,000 bikes (Citibike 2014).

The largest bike sharing offer in Europe exists in Paris. Since 2007 the system was enlarged to 20,000 bikes and more than 1,300 stations. In 2013 the bikes were lent more 35 Million times (Demaio, Meddin 2013). Also the City of London implemented a public bike sharing offer for its citizens. Since 2010 more than 8,000 bikes and over 550 stations were realized. Reasons for implementing bike sharing were relieve of pressure on the public transport system and reduction of motorized traffic for short trips. Since its introduction in 2010 there are around 20 million rents, 30,000 rents a day respectively (TFL 2013).

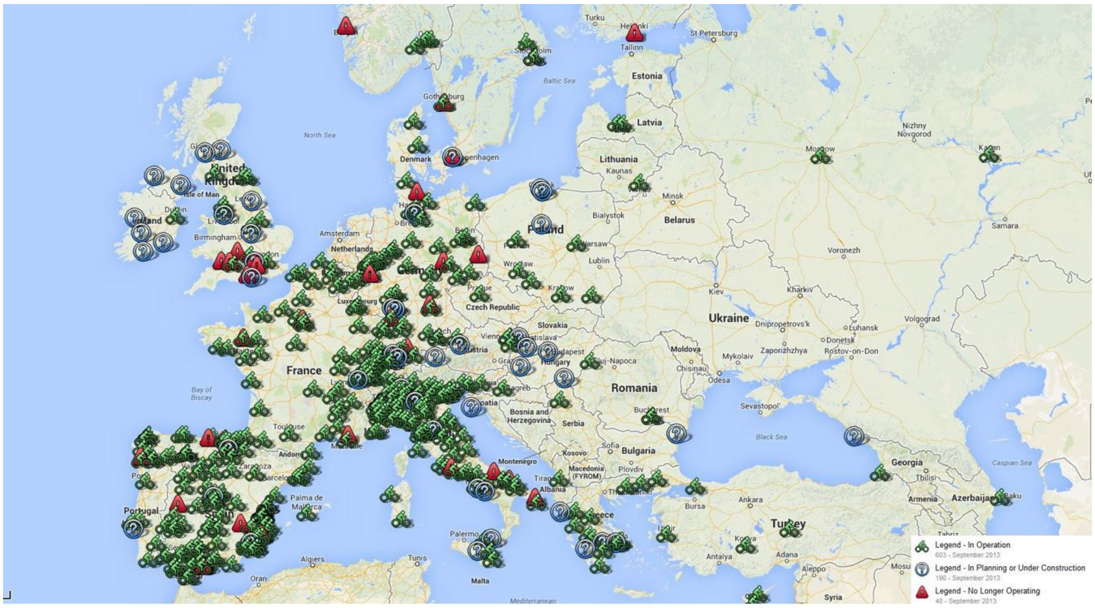


Figure 1: Bike Sharing Systems in Europe (Demaio, Meddin 2013)

1.1. Characteristics, Benefits and Success Factors of Bike Sharing

In contrast to the prevailing CarSharing Systems, with non-location based cars randomly distributed in the cities, the predominant model of current bike sharing systems is location based. The advantage of fixed and partly flexible docking stations with connected terminals is that the bikes can be independently picked up at a random bike station and returned to any other bike station within the system (Raumkom 2011).

Typical characteristics of bike sharing systems (BSS) are fleet size, number and spatial distribution of docking stations, the pricing system, user registration possibilities and different operating models. One can differentiate endogenous and exogenous factors (Büttner et al. 2011).

The endogenous factors describe the physical design of the bike sharing system such as hardware, technology and service elements. The endogenous factors are institutional design elements e.g. the type of operator, contracts and ownership, financing or employment opportunities.

Exogenous factors are specific to each city: the size of the city, climate conditions, mobility-patterns of the citizens, population density, demographic and economic factors. In addition, geographic factors, especially the topology of the landscape, the existing infrastructure as well as the financial and political background of the city play important roles when planning the implementation of a BSS (Büttner et al. 2011).

According to the American Institute for Transportation and Development Policy (ITDP) the benefits of bike sharing can be divided into four different sectors (ITDP 2013):

- Transportation benefits

BSS can provide a serious contribution to reduce congestion and improve the air quality in the cities. When replacing private cars, bike trips can particularly reduce CO2 emissions for short distances of less than 5 kilometers. In combination with public transport, BSS can be a crucial factor to increase the reach of transit. This is significant in parts of the city with a lower density of public transport stations. As an alternative mode for short trips that are usually made by means of public transport, BSS can relieve the public transit system by providing complementary services. For walking distances BSS can increase of accessibility for many inhabitants.

- Economic benefits and job creation

Depending on the scale of the BSS, there are positive effects on revenues and new jobs. Staff is required to maintain and redistribute the bicycles. For example the BSS in Paris employs more than 400 people in full- and half-time positions in different fields of work. Furthermore BSS can generate investments in the local industry for products and services dealing with hardware and software to operate the BSS.

- Health benefits

Bike Sharing improves the health of residents by offering an active transport choice. The physical activity of cycling is recommended to protect health and prevent disease. According to the OBIS Handbook for "Optimizing Bike Sharing in European Cities" just 20 minutes of cycling per day has a noticeable, positive effect on health.

- City image benefits

One of the most important goals of a BSS is to attract new cyclists. Together the visibility of rental bikes and docking stations in the city, and improvements of the cycle infrastructure can attend new customer groups. Another positive side effect is to improve the image of cycling and the city's image and branding e.g. by strengthening its image as a sustainable and eco-friendly city.

According to the ITDP Bikeshare Planning Guide a lot of BSS around the world share common success factors: a typical success factor for a BSS is a dense network with many stations and bikes across the coverage area, with an average spacing of 300 meters between each station to ensure a high accessibility. The bikes must be easy to use, comfortable, robust, easy to find and recognizable by specially designed parts. Besides an intelligent locking system, to check the bikes easily in or out of a docking station, it is also important to have an attractive pricing system to encourage users to use the bikes frequently. Real-time monitoring of station occupancy rates and user information on web applications and mobile phones ensure a frequent flow of information for a high availability and reliability of the BSS (ITDP 2013).

1.2. New developments and trends

In 2009 the German Federal Ministry of Transport, Building and Urban Development launched a competition for innovative public bike rental systems in German cities, to stimulate initiatives and the implementation of pilot projects. The primary objective was to link bike sharing with local public transport to provide new mobility options in city-transport networks. Overall six pilot projects in different cities were funded and evaluated. The evaluation showed that a successful implementation of a BSS depends amongst others on strong local political and media support. As previously described a dense network of docking stations, an attractive pricing system, a state-of-the-art information and reservation system together with comfortable bikes were crucial factors in these pilot projects (Difu 2012).

As shown in Figure 3 a BSS can provide several purposes in different urban areas. In combination with public transport, rental bikes can be used by different target groups, for certain transport options e.g. in the city center, recreational areas or business parks.

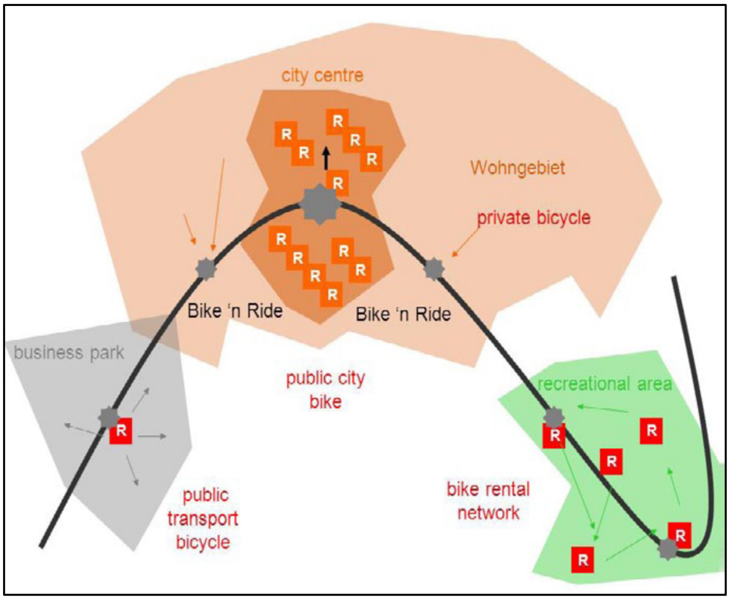


Figure 2: Example for mobility options of BSS in different urban areas (Difu 2012)

A current trend combines BSS with public transport systems by combined rates or universal mobility cards for both systems. Another new development is the transformation from flexible to station based systems. The docking stations can be expanded or simply dismantled and flexibly rebuild at another place depending on current demand. They also can be removed during winter months when demand for rental bikes is lower. In many cities the space for new bike stations is obtained by replacing car parking spaces with a BSS. So the BSS is build up and expanded while the motorized traffic can be reduced simultaneously. Using fast developing communication- and information technologies, wireless communications of station terminals and GPS tracking of the bikes can facilitate registration, renting, payment and localization of free bikes (ITDP 2013).

Another innovative approach and promising development in bike sharing introduces cargo bikes for heavy purchases, bike trailers for children and the implementation of electric assist bikes, also known as E-Bikes or Pedelecs.

2. Impact of Pedelecs on the bike market

While the current sales of electric cars remain low, with less than 12.000 vehicles in Germany sold so far, there is a strong measureable influence of Pedelecs on the bike market in Europe and Germany (Harloff 2014). Within the last couple of years the market for Pedelecs in Europe and Germany shows a significant growth. Since 2010 the number of purchased electrical bikes in Germany increased by more than 100% to 430.000 in 2013. Now there are far more than 1 million E-bikes on the streets of Germany.

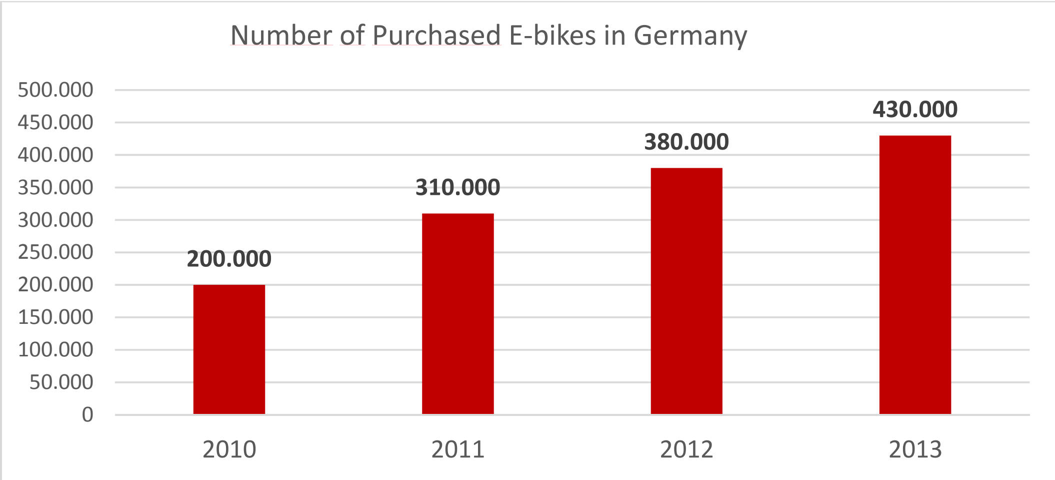


Figure 3: Number of Purchased E-bikes in Germany (ZIV 2013)

The increasing number of E-bikes in Germany also impacts the total number of bicycles (Fig. 5). While there were clearly less than 70 Million bikes in Germany in 2007, the number increased continuously to 71 Million bicycles in 2012. Now three quarters of all Germans live in a household with a bike and every household possesses approximately 2.4 bikes (BMVI 2014).

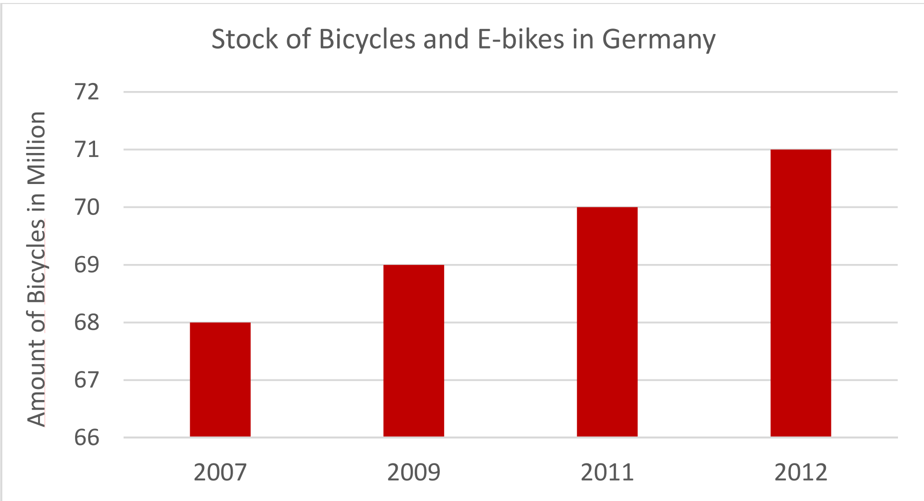


Figure 4: Stock of Bicycles and E-bikes in Germany (ZIV 2013)

Also on a European level there is a clear trend for the growth of E-bikes on the market. An increase by 360% within four years between 2008 and 2012 shows the large demand for these kind of offers.

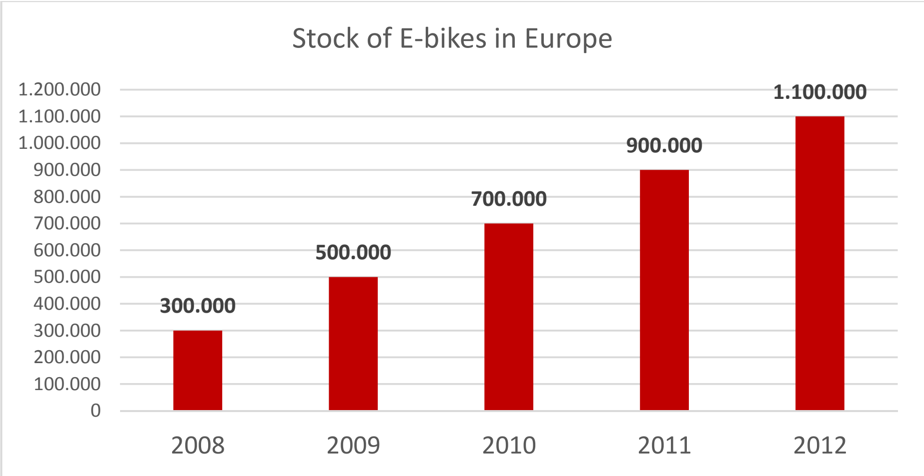


Figure 5: Stock of E-bikes in Europe (ZIV 2013)

The impact of E-bikes on the bike market is even more apparent in comparison with average yearly investment per person into new bikes. Since 2008 the average price for a new bike increased by 6.4% every year. In Germany the amount was attached at 660 € in 2013 (ZIV 2013).

For the use of E-Bikes for commuters there is no long-term data available at the moment. Nevertheless E-Bikes provides also a high capability regarding the energy consumption in comparison to motorized traffic. While an average E-Bike consumes about 1 kWh/100 km an average car needs about 5 liters fuel on 100 km that equates to 50 kWh/100 km. The compensation of energy consumptions with the relation 1:50 means that 50 people using an E-Bike instead of a normal bike is counterbalanced by just one person changing from car to E-Bike (Thiemann-Linden 2013).

In conclusion it seems obvious to think about the integration of E-bikes into BSS and to publicly discuss the opportunities of electrical bicycles within dedicated research projects.

3. Research Project “DC-Laden am Olympiapark”

The department of traffic engineering of the University of the Federal Armed Forces in Munich (UniBW) joined a federal research project for electrical mobility, called “DC-Laden am Olympiapark”. The main objective is to find solutions for very special requirements of charging infrastructure for electric cars and bicycles. Within the project term, the UniBW cooperates with the German Railway Network (DB) to integrate Pedelecs into the existing scheme of the public bike sharing system in Munich, known as Call a Bike. The primary objectives are to find a strategy for a model-based distribution of charging-stations, to implement docking-stations and electric bicycles and to analyze the mobility patterns of possible customers. Moreover, models simulating bike traffic including the special needs for electrical bikes will be developed.

The DB already has some experience in the field of Pedelecs and bike sharing. Since 2011 Pedelecs supplement the public bike sharing system in the city of Stuttgart. Through the federal competition “Innovative public bike rental systems” around 100 Pedelecs were previously made available at 45 charging stations. The launch of the system was accompanied by several technical problems, of hard- and software. Therefore an improved version with new Pedelec-technology is prepared for the future launch in Munich (BMVBS 2012).

3.1. Implementation of Pedelecs into bike sharing schemes

The integration of Pedelecs into modern bike sharing schemes contributes to innovative further development of bike sharing. By integration into BSS the relatively young technology is presented to a wide range of new customers. Simple and convenient access ensures that the customers are enabled to test and try an electric powered vehicle without having any financial or technological risk. While E-bikes and Pedelecs are significantly more expensive than standard bicycles, they enable the rider to cover longer distances and to cycle easily in hilly areas. Covering longer distances can reduce unbalanced distribution of bikes in urban areas with a “challenging” topography and increase the attractiveness of BSS. However the very cost intensive acquirement, maintenance and repair of Pedelecs is another challenging task for modern BSS.

3.2. Finding the right strategy for a distribution of charging stations

Unlike standard bicycles in bike sharing systems, Pedelecs are equipped with batteries, which have to be recharged at electrified stations. It is necessary to develop a sophisticated strategy for the distribution of charging stations. As a primary step, the research project should identify five attractive locations in the City of Munich for a location based Pedelec-Sharing-System (PSS). The UniBW was chosen to develop a location study in Munich and to give a final recommendation for the implementation of the PSS.

20 different locations in the city were inspected in summer 2013 and analyzed according to various criteria. The inspection tours were carried out by scientific experts of the university using two Pedelecs from the DB, also known as E-Call a Bikes (E-CaB).

3.3. Methodology, model and survey of the evaluation scheme

One way of preselection of the 20 locations were interviews of Call a Bike-Staff, asking for popular and heavy frequented places for renting bikes in Munich. Touristic hotspots, important public transport intersections and local city center districts were taken into consideration as well.

Every location was inspected on-site and classified and assessed by three different attributes:

- Target Groups: tourists (non-local), visitors (familiar with places), students, occasional riders and commuters.
- Trip Purpose: leisure or recreational time, Sightseeing, trip to/from work, trip to/from university/school, E-Bike trial ride.
- Transport Connectivity: availability of underground-, tram-, bus- or s-train stations, proximity to main cycle routes, existence of park and ride facilities close by.

In a second step 12 locations out of the 20 were selected for a closer examination. The on-site inspections pointed out that some sites were not suitable e.g. because of lack of space or conflicting uses. A range-chart was produced (Table 1), showing the distances between the different locations. It can be used to evaluate the capabilities of E-bikes for longer trips through the city. Therefore trial rides with the E-CaBs were carried out to determine the maximum range of the batteries. A fully-loaded E-CaB has an average range of about 25 to 30 kilometers, depending on the weight of the cyclist, topography of the operation area, temperature, driving style and many other small variables. Table 1 shows the distance between 12 locations in Munich. The average distance is around 4.8 km, the highest possible distance more than 15 km and the shortest with less than half a kilometer. No location is out of range for the capacity of the E-Cabs and also not accessible for a round trip.

Table 1: Range-Chart of Locations in Munich (UNIBW 2013)

	BMW Welt	Haupt-bahnhof	Odeons platz	Chinesis cher Turm	Allianz Arena	Nymphen burger Schloss	Tierpark	Gärtner platz	Münchner Freiheit	Stachus	Deutsches Museum	Goethe platz
BMW Welt		4,5 km	4,8 km	4,6 km	8,7 km	5,3 km	9,8 km	6,1 km	3,2 km	4,8 km	6,6 km	5,8 km
Hauptbahnhof	4,5 km		1,6 km	3,4 km	11,2 km	5,4 km	5,5 km	1,7 km	3,6 km	0,4 km	2,3 km	1,4 km
Odeonsplatz	4,8 km	1,6 km		1,9 km	9,7 km	6,4 km	5,7 km	1,7 km	2,3 km	1,3 km	1,9 km	2,4 km
Chinesischer Turm	4,7 km	3,4 km	1,9 km		8,8 km	7,6 km	7,0 km	3,4 km	1,6 km	3,1 km	2,9 km	4,2 km
Allianz Arena	8,6 km	11,2 km	9,7 km	8,8 km		13,5 km	15,4 km	11,5 km	7,5 km	10,9 km	11,5 km	12,1 km
Nymphenburger Schloss	5,3 km	5,3 km	6,4 km	7,6 km	13,5 km		9,4 km	7,0 km	6,2 km	5,7 km	7,5 km	6,2 km
Tierpark	9,8 km	5,6 km	5,7 km	7,1 km	15,4 km	9,4 km		4,1 km	7,8 km	5,3 km	4,4 km	4,2 km
Gärtnerplatz	6,1 km	1,7 km	1,7 km	3,4 km	11,5 km	7,0 km	4,1 km		3,7 km	1,4 km	1,0 km	1,5 km
Münchner Freiheit	3,2 km	3,7 km	2,4 km	1,6 km	7,8 km	6,9 km	7,9 km	3,8 km		3,3 km	4,2 km	4,6 km
Stachus	4,8 km	0,4 km	1,3 km	3,1 km	10,9 km	5,7 km	5,2 km	1,4 km	3,3 km		1,9 km	1,5 km
Deutsches Museum	6,6 km	2,3 km	1,9 km	2,9 km	11,5 km	7,5 km	4,4 km	1,0 km	4,2 km	1,9 km		2,3 km
Goetheplatz	5,8 km	1,4 km	2,4 km	4,2 km	12,1 km	6,2 km	4,2 km	1,5 km	4,5 km	1,5 km	2,3 km	

During the on-site inspections a list with attribute-checkboxes was used to collect the information of every location and also to detect possible positions for future PSS docking-stations (Fig. 7). For every location its attribute-description was compiled including a small map-extract, pictures of possible sites and a classification of the attributes.

Figure 6: Location-Attributes Odeonsplatz & BMW Welt Olympiazentrum (UNIBW 2013)

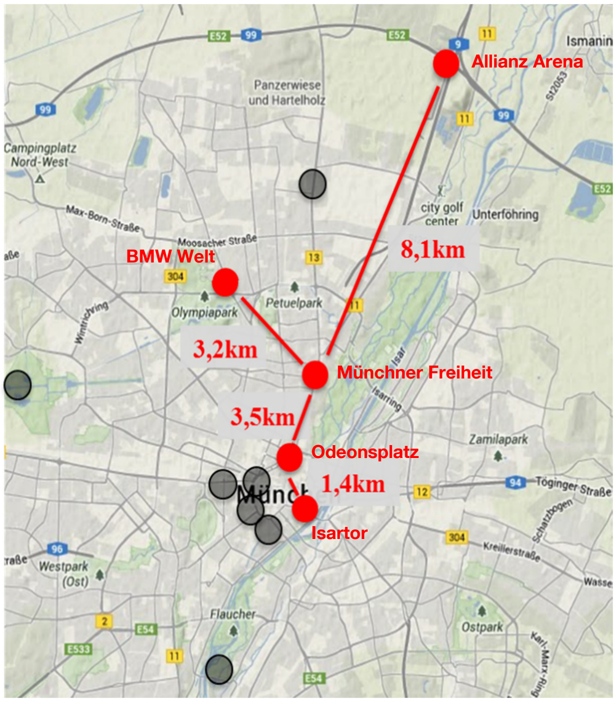
Using the inspections list, every location was assessed for its attributes, using a five-stage-scale beginning from stage one, “not applicable”, to stage five “fully applicable”. The attribute “Target Group” was double weighted, based on the statements of the Call a Bike Staff, who emphasized the importance of the mobility patterns of their customers.

The output is an overall-ranking of the most attractive sites with data in percent of the maximum score of the assessment.

Table 2: Overall Ranking of Locations (UNIBW 2013)

1.	Odeonsplatz	81%
2.	Sendlinger Tor	73%
3.	Stachus	72%
4.	BMW-Welt	70%
5.	Hauptbahnhof	68%
5.	Münchner Freiheit	68%
7.	Gärtnerplatz	65%
8.	Tierpark	64%
9.	Allianz-Arena	61%
10.	Isartor	57%
11.	Nymphenburger Schloss	52%
12.	Domagkstraße	25%

Figure 7: Spatial Distribution of Locations (UNIBW 2013)



The final selection of five suitable locations was made by a comparison of reasonable spatial distances between the different sites and their attractiveness according to the overall-ranking of the assessment (Table 2). The red points in Figure 8 mark the five finally selected spots recommended for future E-bike docking stations in the city. Locations marked by grey points, are either too closely spaced to be a sensible choice or are characterized by a lower ranking

Based on this functional assessment of multiple locations, the first little step to realize a PSS in a large city can be taken. However many examples in other cities show that a station-based bike sharing system can only be successful with a very high number of stations and bicycles, spreaded across the urban area. Possibly the impact of a PSS can be enlarged by combining it with the already existing bike sharing scheme of Call a Bike in Munich.

3.4. Survey among bike sharing users

To verify and confirm the scientific evaluation-method for a location based PSS an online-survey was carried out amongst customers of Call a Bike as frequent users of rental bike systems in German cities. The target group was addressed by a newsletter to all customers of Call a Bike in Germany.

The survey focused on the usage, experience and performance of bike sharing offers in German cities as well as the appreciation of implementation of E-bikes into BSS. The participants of the survey were asked for trip purposes, mobility patterns, attitude towards bike sharing and E-Bikes, and also for their evaluation of general location-types for bike sharing stations and the previously evaluated sites in Munich. Moreover socio-demographic attributes of the participants were investigated.

So far a sample size of more than 420 questionnaires with 23,000 answers was received and pre-analyzed. The survey was still ongoing during the creation of this paper. Preliminary results indicate that there is a strong interest amongst the participants to use E-bikes frequently, especially when available in BSS. The established shared bikes are used predominantly for leisure trips, trips to work and as substitute bikes e.g. for visitors. Car trips might be replaced by bike share leading to an even higher acceptance to substitute car trips, if the traditional BSS would be significantly enlarged and enhanced by the implementation of E-bikes. Regarding the assessment of single locations by the participants living in Munich, there is a particular sentence to keep the existing flex-system for rental bikes, as long as there is no substantial enlargement of the existing bike fleet or a very dense net of stations. A majority of participants nevertheless are preferring rental-locations next to urban district centers, public transport stations and municipal parks.

Regarding the question which sites are most interesting for the participants, the preliminary result shows a high congruence with the scientific assessment. Under the top six locations, scored by the participants of the survey, there are five locations of the top six of the evaluation (Table 3).

Table 3. Ranking comparison of scientific and survey evaluation (UNIBW 2014)

Ranking: Scientific Evaluation		Ranking: Survey Evaluation	
1.	Odeonsplatz	1.	Hauptbahnhof
2.	Sendlinger Tor	2.	Sendlinger Tor
3.	Stachus	3.	Stachus
4.	BMW Welt Olympiapark	4.	Isartor
5.	Hauptbahnhof	5.	Odeonsplatz
6.	Münchner Freiheit	6.	Münchner Freiheit

4. Conclusions

The growing importance of Shareconomy in the field of mobility is reflected by the rise of public bike sharing systems in metropolitan areas. The benefit of reduction of motorized traffic and increase in the quality of life is highly appreciated by many cities. Innovative advancement and implementation of new technologies can have an important influence on mobility patterns of citizens in modern cities. However the operation of BSS is a challenging task, especially when it comes to cost and successful efficiency. Implementing electrical bicycles into BSS is an even more challenging task for operating companies, because the E-bikes and the charging infrastructure must be reliably available for customers. A critical success factor is determined by finding the right strategy for a distribution of charging stations in the urban area. A classification and assessment of different attributes regarding target groups, trip purposes and transport connectivity is necessary to find attractive and demand-orientated locations. The further assessment through surveys amongst possible user-groups can provide valuable information and results to specify the demands of the system.

While Electromobility keeps many new developments particularly in the field of mobility services, sharing-systems such as car sharing or bike sharing provide a simple approach for new customers, without technical or financial risks.

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