Bike-Sharing Systems

Subjects: Sociology

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BSS have raised in popularity in the last years due to their potential share in sustainable cities. Although the first attempts to implement a bike-sharing public service date back to 1965 (Amsterdam), their widespread use arrived with the millennium becoming a vibrant research area whose activity has increased steadily in the last decade.

Keywords: Bike-Sharing Systems ; sustainable vehicle-sharing

1. Introduction

Population concentration in big cities brings higher levels of pollution (due to traffic jams) and has raised the interest in the so-called businesses “as a service” and the sharing economy. Interestingly, the Covid-19 crisis has been a push back for services such as car-sharing while increased awareness about bike-sharing systems (BSS).

Bike-sharing systems (BSS) have probably become the most widespread implementation of the concept of Mobility as a Service (MaaS) [1]. BSS started as a public service in 1965 in Amsterdam with the program named “White Bike”. However, it was not until the past decade that they spread their popularity worldwide [2]. The number of BSS implementations increased from 13 in 2004 to 1956 operational local schemes and approximately 15,254,400 shared bicycles in 2019 [3] (see also [4][5][6]). Visual inspection of the Bike-sharing World Map shows its widespread use, especially in north America, western Europe and Asia [7][8].

The idea behind BSS is simple: a pool of publicly available bicycles placed around the city and ready to be used for a low payment. Each implementation indeed has its own characteristics like:

- Public or private service depending on if it is managed by a private company or by a government administration.
- Dock-based (if it is based on stations picking areas) or free-floating (if just can be picked and dropped around city).
- With a restricted area of use (a delimited perimeter) or without any geographical restriction.
- Implementing different payment methods, incentives to the use of the service, discounts, and prices plans.

2. History of BSS

Attending to their characteristics and according to [9][10][11] there are five generations of BSS shown in Table 1.

Table 1. A brief chronology of Bike-sharing systems (BSS) generations according to Refs. [9][10][11].

Generation	Year of Appearance	Description	Implementation Example	Payment Method
First	**1965**	**They erroneously assume that people would have a civic behavior in the use of the service. Because of that, they planned the service without including docking stations and control systems to avoid thefts and vandalism.**	**Amsterdam, White bikes**	**Free of charge**
Second	**1992**	**Systems of bike-loans based on docking stations (coin-based payment).**	**Copenhagen, “Bycicklen” City bikes**	**Coin -deposit**
Third	**1998**	**This generation introduced the identification of agents involved in the service (users, bikes, trips, stations, etc.). New payment methods like credit cards or specific charge cards were also included.**	**Rennes, “Vélo à la carte”**	**Smart magnetic card systems**

Generation	Year of Appearance	Description	Implementation Example	Payment Method
Fourth	**2005**	**Several innovations were introduced in this generation like solar-powered docking stations, electric bikes, GPS tracking systems and integration with mobile applications.**	**Lyon, "Vélo'v"**	**Credit card, smart card and App based payments**
Fifth	**2016**	**The improvement of this generation is based on the elimination of docking stations. This allows users to pick up and leave bikes in specific zones of the sidewalks but without being anchored to a base-station and without also being tied with safety chains.**	**Shanghai, "Mobike"**	**App based payments**

Focusing our attention on the BSS based on docking-stations, we can define them as a set of stations distributed in different locations around the city. Each station has bike slots where users can pick-up a bike or leave the one that they have already used. Due to imbalanced demands, some stations might out of bikes while others get fully occupied and can be overloaded by concurrent end trips. This problem has been identified in literature with several names: imbalance, rebalance, repositioning, and balancing are the most used.

BSS operators (namely company or government administration that owns the service) mitigate the effect of this asymmetric demand, getting the bicycles to be replenished at the top origin stations and releasing docking-bases at the top destination stations. It is worth remarking that how the owners manage this problem is directly translated into the user level satisfaction of the service.

Options used to solve this situation can be divided into two strategies [12]: Operator-based or User-based repositioning. The former consists of using some vehicles (typically trucks) to move bikes from one station to another one. Alternatively, in user-based repositioning, the users, instead of BSS employees, are incentivized to leave or pick-up bikes in specific stations. As mentioned in [13] Operator-based strategy seems to be more effective in docking-station based BSS, while user-based strategy retrieves better results in dockless BSS. Both strategies can be implemented from the static point of view (redistributing bikes on specific time frames) or dynamic one (the operator redistributes them in real time [13]). The current trend shows a hybrid solution, combining the different rebalancing modes.

Because there are several possible solutions for this problem, we decided to identify available review literature focused on the repositioning problem. Firstly, we decided to classify available research in BSS area. Although BSS implementations started years ago, it is not until 2010 that relevant research appears in this field. According to [14] BSS research can be classified into four stages shown in Table 2.

Table 2. Four stages in which BSS research can be classified according to Ref. [14] and attending to publish period, research topic and bike generation.

Stages	Period	Main Research Topics	Bike-Sharing Generation	Research Topics Trend
First	**2010–2012**	**Safety and policy**	**3rd and 4th**	
Second	**2013–2014**	**Bike-sharing form benefit, system and impact point of view.**	**3rd and 4th**	
Third	**2015**	**Subtopics of previous period are subdivided and studied in detail:** • Optimization • Customer behavior • System implementations (built environment, design and infrastructure)	**3rd, 4th and 5th**	
Fourth	**2016–2018**	**Continue the tendency of subdivide topics and get detailed research:** • Demand • Bikes and stations rebalancing and • redistribution. • Usage (analyzing impact variables like weather, choice, user segment, day type, etc.)	**4th and 5th**	
	Last two years 2019–2020	**External impacts, barriers and bike-sharing usage/customer behavior specially focus on 5th generation BSS**	**4th and 5th**	

In the fourth one (2016–2018) research is mainly focused on demand, rebalancing, and redistributions of bikes among stations problem. However, the literature on BSS is scattered in different fields which makes it hard for new researchers to bring ideas that can push further this service as a competing strategy to achieve more sustainable cities. For example, in the last years, there is a growing interest in understanding patterns that explain the use of BSS. References for docking-based BSS like [15][16] or dockless ones like [17][18] can be found. However, rebalance data is not used for that purpose. In this review paper, we attempt to review BSS research focused on the “rebalancing problem”. Only for BSS implementations based on docking-stations (fourth generation of BSS).

3. Conclusions

Bicycle-sharing systems (BSS) has been recognized as an important actor towards the construction of sustainable cities and it has experienced an unprecedented expansion worldwide.

We have clearly seen, as it was also recognized in Ref. [19], that BSS in different cities have different characteristics which means that different redistribution mechanisms will be required (as a consequence of the topology, socioeconomic factors and climatology). A common characteristic in the practical totality of the proposed redistribution mechanisms, is the use of a fleet of vehicles to perform this action. The contradictory part is that most of them use highly polluting vehicles what contradicts the goal of alleviating the problem of a sustainable transport. Interestingly, to our knowledge, except for Ref. [20], there are not others works computing the carbon footprint of different BSS rebalancing strategies, so our work paves the ground to this sort of approach.

We have also identified that, in the last years, modern algorithms like visualization or machine leaning based ones, has been used to provide possible solutions to the rebalancing problem. Those algorithms do not fit in the classical used algorithm taxonomy in this field, and because of that we suggest to include a new group for include inside it this kind of new approaches.

Finally, we identify the following open questions and research lines in the BSS rebalancing problem. (1) Surprisingly, all the existing works addresses the BSS as a sustainable alternative in a non-sustainable way as they ignore the impact of rebalancing using polluting vehicles. (2) The “rebalance problem” has been studied in other scenarios (other vehicle-sharing systems, classical pickup and drop problems of deliverable services, etc.). However, we have not retrieved

comparative studies comparing solutions adopted in other fields and how it would be adopted in the BSS. (3) Currently, most of the newly implanted BSS solutions are dockless, so we expect a considerable raise of publications in that direction in the next decade. We anticipate that most of the solutions adopted for BSS would be obsolete what paves the ground for further developments adapted to its idiosyncrasies. (4) Currently, most of the solutions do not exploit the vast amount of user-centric data using machine learning techniques that could improve considerably the personalization of the service. (5) Finally, we guess that comparative analyses (in terms of sustainability as well as economic or social penetration) between dock-based and dockless BSS systems would assist public administrations and companies to evaluate the decision of migrating from a one BSS type to another.

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