Bicycle Sharing Systems

Subjects: Others

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Bicycle Sharing Systems (BSSs) are a novel transport mode that benefits from the new sharing economy. BSSs provide flexible mobility services to users who can rent or borrow a bicycle to move around the city in a cheap, healthy, and environmentally friendly way.

Keywords: public transport systems ; docking stations ; clustering ; prediction ; Internet of shared bicycles ; shared economy

1. Introduction

BSSs date back to 1965, when the White Bicycle Plan provided 50 free to use white bicycles in Amsterdam. Since then, a multitude of BSSs have emerged, incorporating new technologies and market ideas to extend their use and functionalities.

Nowadays, BSSs are considered an inherent part of the mobility services in a city[1]. In this respect, BSSs show a distinct characteristic: not only can they be regarded as transport, but also as leisure. Bicycles are currently used as a means of tourism and sport, which is not observed in other transport modes[2].

The evident benefits of BSSs have opened a set of research and development lines in order to optimize their operation and extend their services.

2. Clustering

The first problem to tackle on a BSS is the design of the network of bicycle stations, which is key to the eventual success of the system. This factor is especially relevant given that, in most cases, BSSs are funded by public administrations, which are always restricted to fixed budgets and thus need to maximize their investment. This is yet an unresolved problem that requires extended efforts from both scientific and technological fields.

Furthermore, an optimally designed and deployed BSS may still not be viable as it has to face a fundamental issue: its operational costs. Every BSS presents an unbalanced demand on the stations within its network. In addition, this disproportion occurs in both space and time, which increases the complexity of the problem. In order to solve it, BSSs perform rebalancing operations. The fundamentals of rebalancing are simple: a truck distributes bicycles among the set of stations in order to guarantee that both bicycles and docks are always available throughout the day. The truck can either get bicycles from a central depot or move them from one station to another. Consequently, rebalancing is essentially a routing problem that can be mathematically formulated[3].

In order to solve it in an efficient way, rebalancing must include a first phase of clustering, which groups the docking stations into sets with similar characteristics. Clustering can dramatically reduce the total length of the routes trucks have to travel to move bicycles to and from docking stations. This has a major positive impact on the operational costs and on the reduction of the associated emissions. However, the real impact of clustering greatly extends beyond rebalancing as it provides a meaningful knowledge about the actual operation of the BSS and the mobility in the city[4].

3. Prediction

In order to fulfill the optimization of the operation of a BSS, we also need to anticipate problematic situations. This means predicting future states of docking stations and triggering the required actions.

Prediction is always a complex task given the stochastic nature of users' behavior. This issue can be faced by the use of either theoretical modeling or empirical approaches based on artificial intelligence. Theoretical models require a precise representation of all relevant data, specifically the pick-up and return profiles in every docking station and the connections among them given the road infrastructure. For its part, empirical approaches transparently encode this information into their internal representation, easing the definition of the problem and providing high predictive capabilities even when only partial data is available.

4. Monitoring platform

In addition to their basic transportation service, BSSs can also be observed as a potential platform to collect relevant data from the city. Under this perspective, shared bicycles evolve into mobile sensors, able to retrieve quality air measurements, noise levels, or congestions, among others. Thus, BSSs develop into narrow-band Internet of Things (NB-IoT) applications.

This transition opens up a new set of challenges. At a local level, we need to reduce energy and computation costs by means of data-fusion or smart routing. At a global level, the BSS needs to adopt new models in order to deal with the issues this extended complexity imposes. In this respect, a BSS have been recently approached as the Internet of Shared Bikes (IoSB)[5].

The IoSB model allows us to separate the different layers we need to provide the whole set of services associated with BSSs. In addition, it contributes to the optimization of the efficiency of the computation and communication processes. In this environment, edge computing emerges as a means to optimize the use and operation of each docking station.

5. Economic, social and environmental sustainability

BSSs can provide a positive contribution to promoting sustainable mobility. In this respect, it is crucial to explore to what extent BSSs encourage reasonable mobility behaviors, bringing about benefits for society. Moreover, it is necessary to explore which are the best governance and business models in order to ensure the right integration with traditional modes to improve the economic, social and environmental sustainability[6].

In order to do so, we need to characterize the current demand of BSSs and identify the main reasons driving users' choice. In addition, the impact of BSSs on traditional modes of transport must be assessed. Finally, this line of action must develop new governance and business models to integrate BSSs to traditional mobility solutions in such a way that the social welfare is optimized.

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