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Enhancing the utilization of public bike sharing systems using return anxiety information

Ming-Fong Tsai [a,*], Ping Chen [b], Yap Jia Hong [b]

[a] Department of Electronic Engineering, National United University, Taiwan
[b] Department of Information Engineering and Computer Science, Feng Chia University, Taiwan

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ABSTRACT

Public Bike Sharing Systems (PBSSs) have become popular as mass transportation tools. Along with the growth of the population using them, disadvantages of PBSS are emerging, for example, when there are no bikes available for users to rent or no vacant parking lots to which bikes can be returned. To make up for this disadvantage, users are allowed to apply for fee discounts and obtain real-time information in advance from the Internet. The two main problems are full stations or lack of available bikes. But in hot spots or at specific hot times, even when users know the current station information, it is not possible to guarantee whether there will be parking lots or available bikes in the next second.

To prevent the decline of the reference value of real-time bike information caused by large numbers of users, we collect the number of bikes near stations and real-time information in bike stations to form return anxiety information. When a station is nearly full or there are many bikes near the station, the return anxiety information value will increase. When users enquire about returning bikes to stations, they can refer to the return anxiety information. The higher the return anxiety information value, the lower the user's tendency to return the bike. In the implementation, our study develops an android application to collect basic data and uses a Petri Net to simulate the PBSS scenario. Various rates of user trust are used to verify the reference value of return anxiety information.

1. Introduction

Owing to the advantages in terms of environmental protection and energy conservation offered by the present public bike-sharing systems (PBSSs), they have become more and more popular in cities. Taiwan's PBBS started to run in 2009. At present, PBSSs in all big cities have accumulated 100 million journeys. A PBSS is a system that allows citizens to rapidly rent bikes in cities [1]. It contains several rental stations. Users can rent bikes at Station A and return them to other stations or to Station A after their journey. A PBSS can extend its service area through expanding the number of rental stations. Taking Taiwan as an example, the downtown areas of all main cities are taken as the main service areas with dense stations, and dispersed stations are set up in other cities. PBSS provides users with a transportation tool suitable for short-distance journeys in cities. Thus, the distance between bike rental stations is short and each bike rental station has a certain number of bikes. In busy areas, there are more parking lots in the rental station. In comparison, the utilization rate of nearby stations is low. In addition to the fact that the popularity of spots affects the utilization rate of PBBS, the timing affects it as well. For example, during the period from 7 to 8 a.m. from Monday to Friday, numerous bikes are returned to bike rental stations near schools, and at 5 p.m., after school, many bikes are rented from bike rental stations.

Along with the growth of the number of PBSS users, when the number of users is high, it has a great impact on specific rental stations. When bike rental stations lack bikes or are in full condition, respectively, users are not able to rent or return bikes. The PBSS should avoid this situation; however, along with the increase in the number of users, a lack of bikes and full stations have become severe problems that cannot be neglected. In addition to the conditions of a lack of bikes and full stations caused by the increasing number of users, the utilization rate of PBSS is uneven. In the centre of a hot spot, there is a bike rental station A with 100 parking lots. This Station A is used by 500 users every day, but Station B, which is 200 m from Station A, only has 40 parking lots and is used by only 10 users. When most users only use Station A, Station A usually lacks bikes or is full, decreasing its efficiency. However, the nearby Station B is usually unused.

When the higher number of users causes a decrease in the efficiency of the PBBS, users are unable to use it, causing loss

* Corresponding author.
E-mail addresses: mingfongtsai@gmail.com, mftsai@nuu.edu.tw (M.-F. Tsai), imdadaeye@gmail.com (P. Chen), yapjiahong@gmail.com (Y.J. Hong).

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of operation and causing users to have doubts about using this system in the future. At present, three approaches are used to solve problems such as full stations and a lack of bikes:

- Transport truck scheduling: The operating company sends trucks to each bike rental station to supply or remove bikes. This method allows the bike rental station to maintain a certain number of bikes and available bikes; however, users cannot predict the time when trucks will start to schedule bikes so this fails to solve the user's problem in time.
- Fee discount: This method solves the problem of the station being full so that users cannot return bikes. When Station A is full, users cannot return bikes there. At this time, the users need to ride the bikes to other nearby stations to return them. When Station A is full, users cannot return their bikes there. At this time, they have to ride their bikes to nearby stations to return them. The distance between Station A and the actual bike return station means they can apply for a fee discount from the operating company.
- Real-time in-station information. Real-time information includes real-time information about the remaining parking lots in each station and number of available bikes; users can browse the webpage or use the app to enquire about the number of available bikes and remaining parking lots in each rental station.

Among the three solutions considered to solve these problems, transport trucks are the most frequently applied approach to maintain a suitable number of bikes in stations. Transport trucks can effectively supply or remove bikes, but when station fullness and a lack of bikes happen outside the truck's scheduled time, this solution cannot immediately solve the problem and users need to wait for the truck. Also, users cannot know the route and time schedule of trucks. Thus, transport truck scheduling is not an efficient way to fulfil user's real-time requirements. Fee discounts are a passive compensation method. When stations are full or there is a lack of bikes, the fee discount cannot solve the fundamental problems but it can be the last line of defence in PBSS operation.

Real-time in-station information allows users to enquire whether there are bikes or vacancies available in the bike rental station. This method is the only way for users to achieve mental preparation. The disadvantage of this method is that near to stations in hot times or hot spots, there might be many rentals and returns in a short time. When users are enquiring about real-time in-station information, five vacant parking lots may be displayed but when the user arrives at the station, there might be no vacancy and there might be only a ten-minute time difference. Real-time in-station information is good reference information for users. This study will utilize return anxiety information to allow users to predict the future and accordingly improve real-time in-station information.

As addressed above, the disadvantage of real-time in-station information is that it cannot provide helpful information when many users use bikes in a short period of time. This is the point that this study stresses in order to make the greatest improvements. Also, we propose an effective solution for users when the stations are full or there is a lack of parking lots. If we expand the real-time in-station information to the number of bikes near bike rental stations, users will be able to precisely diagnose the future changes. To explicate concretely, when User A enquires about information regarding the station in order to return a bike, when return anxiety information is not referred to, it displays the available bikes and remaining parking lots as "available bikes: 42, remaining parking lots: 5", so User A might think that there are vacancies in the station and head to the station to return the bike. But in fact, many users are near the station occupying the parking lots. When User A arrives at the station, there will be no vacancies for returning bikes; if User A adopts the assistance of return anxiety information when intending to return a bike to a certain station, the return anxiety information can provide a reference value according to the fullness condition of the stations or number of bikes near the stations. When the return anxiety information value is high, it is unsuitable for users to return bikes. With the assistance of return anxiety information, it will display data like "available bikes: 42, remaining parking lots: 5, nearby bikes: 7, return anxiety information: high". User A therefore knows that the return anxiety information value of the station is high and it is unsuitable to return the bike because although there are five vacant parking lots, there are seven bikes nearby. Before User A arrives at the station, the vacant parking lots might have been occupied.

This study utilizes the number of bikes near the bike station, taking this information as the reference for bike return in the future timing and integrates information collected about nearby bikes and real-time information from the bike rental station to form the return anxiety information. When the station is nearly full or there are numerous bikes near the station, the return anxiety information value will be high and users tend to return bikes to stations with lower return anxiety information values. We further analyse the rates of users trusting that return anxiety information can effectively improve the full condition of stations. Although at present, we do not have approaches to obtain the number of bikes near stations, we use a Petri Net to simulate PBSS and add the return anxiety information to implement the simulation. This study is divided into five Sections. Section 1 explicates the research background, motivation for researching PBSS, and improvement direction and goals; Section 2 explores the related works, reviews the present research direction of PBSS, and explains the application of the Petri Net (PN); Section 3 analyses the PBSS scenario and problems and the design scenario models, explaining the concept and implementation of return anxiety information; Section 4 presents the experimental results and discussion; Section 5 presents the research conclusions and discusses the future research direction.

2. Related works

2.1. Public bike system

A variety of studies on PBSS have focused on scheduling bikes to avoid a long-term lack of vacancies or lack of available bikes in specific bike rental stations. Some proposed approaches included utilizing delivered real-time information from bike stations and optimizing the scheduling route [2]. The real-time information which can be utilized includes the GPS coordinates of bikes [3]; in addition to utilizing real-time information, some did not tend to improve the scheduling method but controlled the information signals of bike stations so that users could balance their bikes by themselves [4]. At present, PBSS studies stress data analysis. Regardless of whether they use existing data to build a model to improve bike scheduling [5] or use data from years of observation to predict the flow of bike traffic, most studies simply utilize old data to conduct the data analysis and use improvement methods to analyse other improved data to perform a comparison [6]. This study uses a Petri Net to simulate the PBSS of an area and adds an improvement method to the PN model to compare the improvement status. Although most methods which are effective at improving PBSSs use a prediction method to predict the conditions of station fullness or lack of bikes and send scheduling trucks to schedule bikes, this method cannot prevent massive surges of tourists. This study aims to integrate return anxiety information and provide it to users so that they can make better judgements about returning bikes and the number of bikes between stations can be balanced.

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