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IMPACT OF PUBLIC BIKE SHARING: EXPERIENCES FROM NINGBO, CHINA

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ABSTRACT

We report the experiences of the bike sharing system in Ningbo, China. To analyze the impact of the system, system log data are collected for the whole month of May 2014 (with more than 1.7 million usage records), supplemented by questionnaire data from 1,856 respondents. Our results show that public bike usage follows the same pattern as road traffic, with morning and evening peaks on week days. In terms of mode substitution, 16% of public bike trips would have been made by private cars. In average, each public bike is used 3.7 times per day, with each trip lasting around 23 minutes and covering around 3.5 kilometre. This translates into a reduction of car travel by more than 11 million kilometre per year, a significant contribution to the sustainability of urban transport in Ningbo.

Keywords: bike sharing, public transport, cycling, user analysis, impact analysis

1. INTRODUCTION

Bike sharing systems have become increasingly popular over the past decades. It solves the “last mile” problem and is well known for its benefits in improved accessibility, reduced congestion and emission, as well as health benefits. Many cities have implemented their own public bike schemes for the purpose of car reduction, bike promotion, and “last mile” connection to public transport.

Three key issues are vital for the sustainable development of public bike sharing system: (a) bike usage rate, (b) bike & ride transfer rate, and (c) car substitution rate. Globally, public bicycle usage rates usually vary from around three to eight trips per bike per day (Fishman *et al.*, 2013). Two exceptions are Melbourne and Brisbane (Australia’s only two bike sharing programs) which have usage rates less than one, significantly lower than other cities. It is believed that the legal requirement of wearing helmet while cycling in Australian cities may have contributed to this.

In terms of bike & ride transfer rate, results from Dublin (Murphy, 2010) show that 55% of public bike riders use bike as part of a trip chain (multimodal travel). The results from Beijing and Shanghai (Yang *et al.*, 2011) show that 58% and 55% of public bike users, respectively, combine the metro and bike modes for their trips.

The car substitution rate, i.e. the proportion of public bike users who switch to cycling from a private car, varies greatly from city to city. The cities of Melbourne, Brisbane, and Minneapolis/St. Paul (Minnesota) all reported a high car substitution rate of about 20% (Fishman *et al.*, 2014). However, the cities of Washington D.C., Lyon, and Dublin reported a low substitution rate of roughly 7% (Fishman *et al.*, 2013; Murphy, 2010). Beijing, Shanghai, and Hangzhou reported that only 5.2%, 0.46% and 4% of bike trips,

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respectively, were substituting private car trips (Shaheen *et al.*, 2010; Yang *et al.*, 2011).

2. NINGBO PUBLIC BIKE SHARING

Encouraged by the benefit of congestion reduction and the successful practices in other cities, the city of Ningbo, China, introduced its public bike scheme in September 2013. Ningbo bike sharing system deployed up to 15,000 bikes and docks at 600 public bike stations located in four central districts by the first year end, providing 24-hour public bike rental service. By the end of 2015, the number of stations increased to 1069, with 30,035 bikes and docks deployed throughout the city.

A typical service station consists of 25 docks, which are hard wired and equipped with an automatic lock system for locking and releasing the bikes. The information of bike rental or return is communicated wirelessly through a middle control box to the data centre. Most of the bike service sites had been constructed for the purpose of "last mile" connection to public transportation. They are therefore located nearby bus stops and residential neighbourhoods.

As of June 2016, a total of 488,103 Integrated Circuit (IC) cards have been issued to the registered users. To rent a bike, users tap their cards on the docks and the bikes are then unlocked for pick up. To return a bike, the user pushes the bike into the dock and then taps their card for check out. No rental fee is charged for the first hour, with sharp price rises thereafter (1 RMB per hour after the first hour; 3 RMB per hour after the third hour).

3. METHODOLOGY

3.1 Questionnaire survey

To study the characteristics of the Ningbo bike sharing system, a field survey was conducted at 111 service sites across four districts of the city (Haishu, Jiangdong, Jiangbei and Yinzhou) between July 6th and July 10th, 2014. The survey targets public bike riders, with questions mainly covering the public bike usage of the respondents, including motivation and use pattern. A group of 18 investigators approached the bike users and obtained a total of 1,856 valid responses. This group of respondents accounted for 2% of daily public bike riders or 0.8% of all registered users at the time of the survey (223,090 registered users).

Of the 1,856 respondents in this survey, 79.6% are aged between 18 and 50, with male accounting for 53.8% of the respondents. In terms of transportation means, 50.3% own private cars, 52.7% own private bikes, and 36.3% own electric bikes. This sample of respondents is therefore considered representative of the general public bike users.

3.2 Usage data

Besides the questionnaire survey, one month of rental transaction records of IC cards were analyzed. For this purpose the data from May 2014 were obtained, which contained 2.55 million bike rental records including the attributes of IC card identification (ID), bike ID, rent time, rent dock ID, return time, and return dock ID etc. The data were carefully checked and the repeated records with exactly same attribute values were eliminated, which may be duplicated redundantly due to wireless communication problems. The records with trip time shorter than one minute were also eliminated, which are believed to be unrealistic trips due to bike problems, usually a case where the user did not leave too far from the service site (shorter than 250 meters) and realized the bike problem and soon returned the faulted bike to the original service site. Totally 0.82 million of invalid records were eliminated including 0.54 million of duplicated records. Therefore only 1.73 million bike transaction records were left as valid data for analysis.

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4. CYCLING DEMAND ANALYSIS

4.1 Temporal analysis

Figure 1 shows the hourly rent amount over the whole month of May 2014. As can be seen, there is an obvious cyclic pattern in the amount of bike rentals over time. This pattern can be characterized by: (1) from week to week, the total amount is comparable; (2) within each week, working days have much higher (+30%) daily amounts than weekends and holidays; (3) within each day, there are obvious morning peak and evening peak; the top 4 hours account for about 40% of the daily amount of bike rentals (Figure 2).

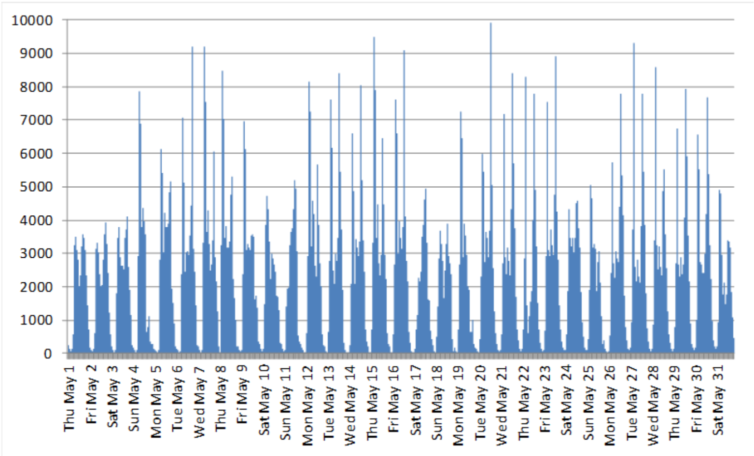

Figure 1. Distribution of hourly bike rent amount over time: May 2014 (total = 1,729,409); note here that May 1~3 were public holidays and May 4 was a working day.

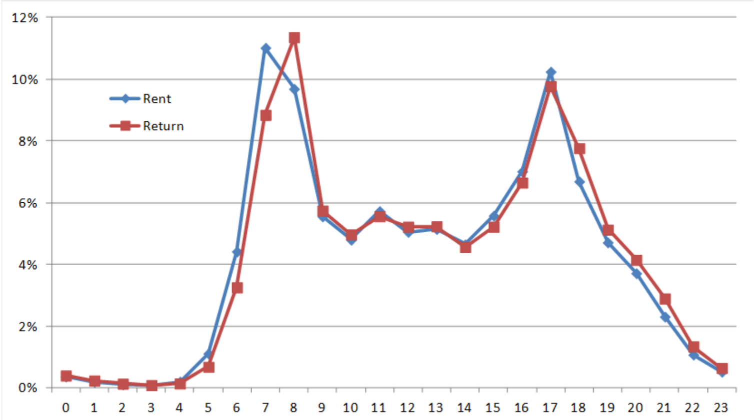

Figure 2. Percentage distribution of bike rent/return amount over hour of the day: daily average of May 2014.

4.2 Station Classification

When the distribution over hour of the day is analyzed for individual stations, it is found that there are different types of stations in terms of the distribution pattern:

(a) Type I stations (Figure 3a) show a concentrated morning rent peak, with a slightly dispersed evening return peak. Such stations are mostly located at residential areas and the majority of public bike users are commuters leaving home for work.

(b) Type II stations (Figure 3b) show, contrary to type I, a concentrated morning return peak, with a

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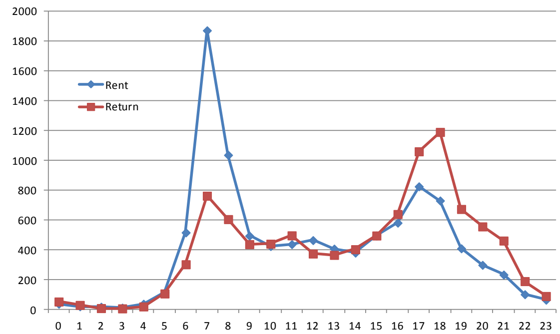
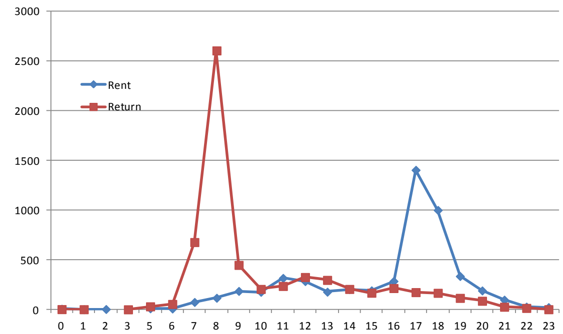
slightly dispersed evening rent peak. Such stations are mostly located at business districts and the majority of public bikes users are commuters arriving at their work places.

(c) Type III stations (Figure 3c) is unique in the sense that both rent and return amounts peak at the morning rush hour, with no evening peak. Such stations are mostly next to buildings of “public services”. A characteristic of these buildings is

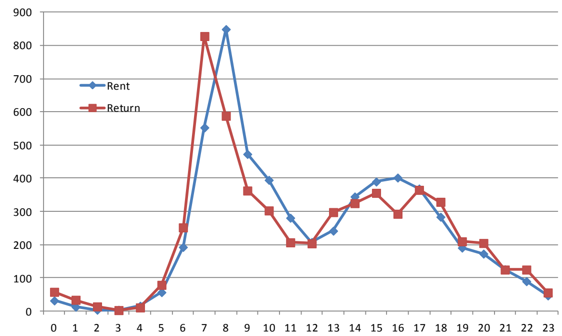
(d) Other stations (Figure 4).



(a) Baihe Park

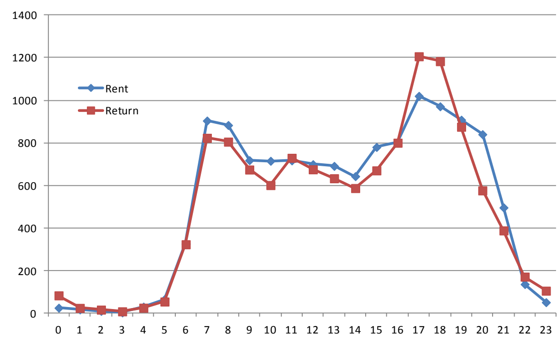


(b) Shanshan Plaza

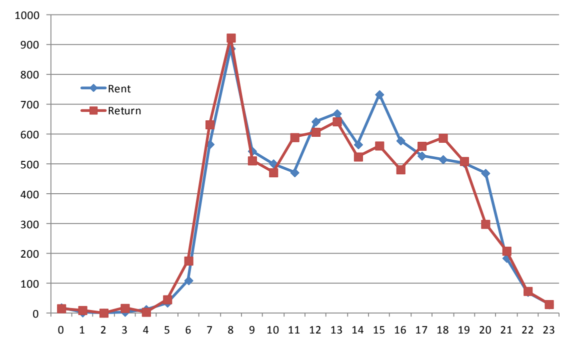


(c) Li Huili Hospital

Figure 3. Distribution of bike rent/return amount at selected stations: (a) Type I (“residential”) with morning rent peak and evening return peak; (b) Type II (“business district”) with morning return peak and evening rent peak; (c) Type III (“public services”): morning rent and return peak, with flattened evening peak/plateau.



(a) Cuibai Road Auchan Supermarket



(b) Drum Tower North Gate

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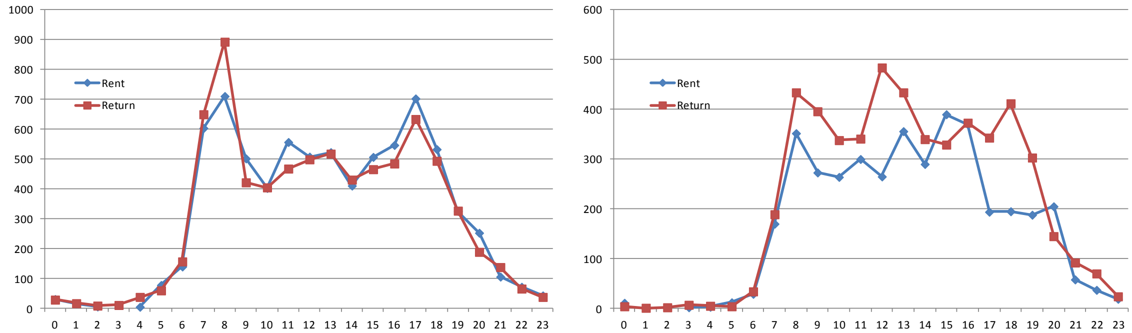


(c) Temple of Seven Pagodas (d) Municipal Library

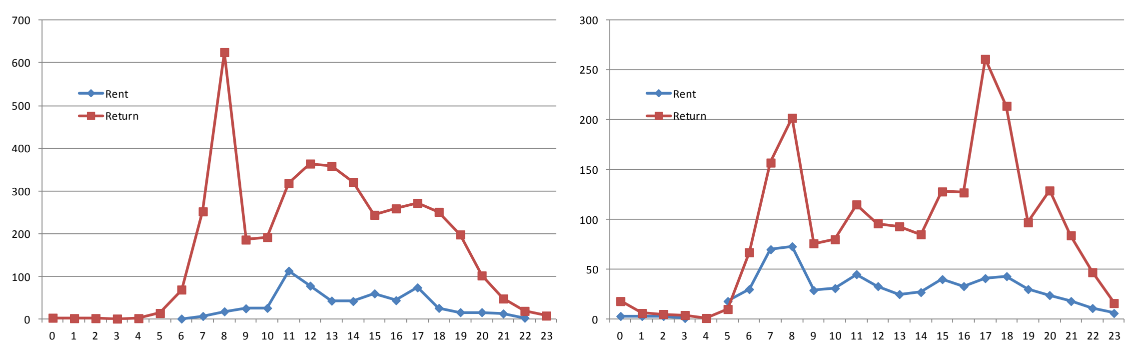
Figure 4. Other stations (mixed development): morning & evening peak, often with midday peak/plateau.

Other studies have identified similar classifications. A study on the bike sharing system in Reggio Emilia, Italy (Dell'Amico *et al.*, 2014) classified the 13 stations there into three groups: the first group with a morning return peak and afternoon/evening rent peak (similar to Type II here), the second group with a morning rent peak and afternoon return peak (similar to Type I), and the third group with both rent and return peaks in the morning and evening.

4.3 Rent-return imbalance

When examining the rent-return imbalance per station, it is found that stations with the biggest difference in rent/return amount (Figure 5) are not the busiest stations, i.e. they are not among the stations with the highest total rent/return amount. In other words, the busiest stations are very well self-balanced.

An additional finding is that the imbalance problem is much severer with excessive return amounts than with excessive rent amounts. That is, the absolute imbalance for stations with negative rent-return balance (i.e. rent amount less than return amount) is generally larger than for stations with positive rent-return balance. It is postulated that those stations with highly negative rent-return balance are places of "gathering", where people gather for various purposes (e.g. banquets, parties, meetings, lectures). People arrive individually with various modes of transport, one of which is via public bikes. When the gathering is ended, there is a tendency for people to depart together in (small) groups. The return trip is then less likely to be made via public bikes: people may share a car and get dropped off or they may share a taxi.



(a) Ningbo World Hotel (b) Renmin Road middle

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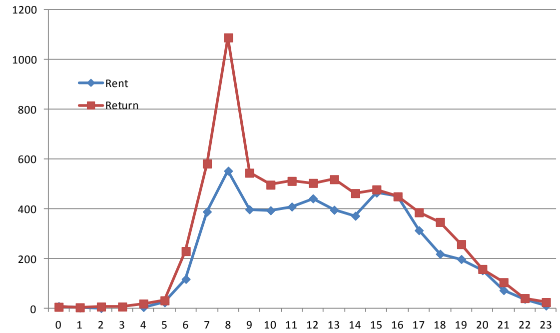
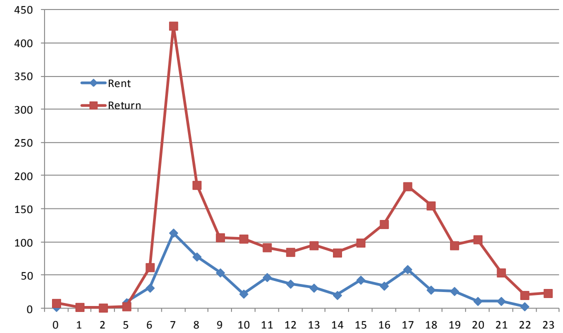


(c) Petrol Plaza



(d) College of Tourism

Figure 5. Stations with largest rent-return imbalances (mostly places of "gathering"), all with negative rent-return balance.

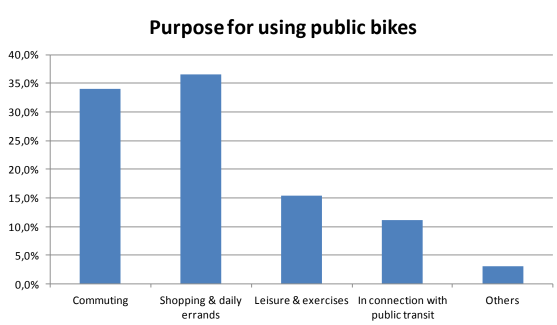
5. USER ANALYSIS

The survey results show that 70% of public bike users ride the bike directly to their final destination and only 30.0% use the bikes to transfer to other transit modes. This is surprising in the sense that the bike sharing system was built to solve the "last mile" problem and a much higher percentage of users had been expected to use the bikes for connecting to other modes. This suggests to the operators that future expansion of the system should put more focus on direct trips instead of building service sites mainly near bus stops.

Another interesting finding is that 16% of the bike riders would have used their cars for the same trips, had bike sharing not been implemented. This car substitution rate is higher than the average amount (7%) from other cities and matches the level of the cities such as Melbourne, Brisbane, and Minneapolis/St. Paul (Minnesota). It is believed that the city development characteristics of Ningbo and its bike deployment scale have contributed to the high substitution rate.

In terms of user satisfaction, 99% of the respondents are satisfied overall with the bike sharing system. 40% are unsatisfied with the shortage of bikes/docks for rental/return during peak times. The survey also suggests that 47.6% of the public bike trips replace the bus trips, 15.6% replace electric bike/private bike, and 12.3% replace walk. Known the 30% of bus & ride transfer rate, this suggests that the bike sharing system actually reduces the amount of bus passengers for about 14, 000 trips per day, 1% of daily public transport trips, and does not lead to overcrowding of buses.

The survey also reports that 47% of riders use the bike for commuting, and 35% for shopping and entertainment (Figure 6). Of the surveyed users, 37.2% of them are "loyal" users who use public bike more than 6 times a week, 46.4% of them normally take the bike 2 to 6 times a week, and 16.4% of them below 2 times a week (Figure 7).



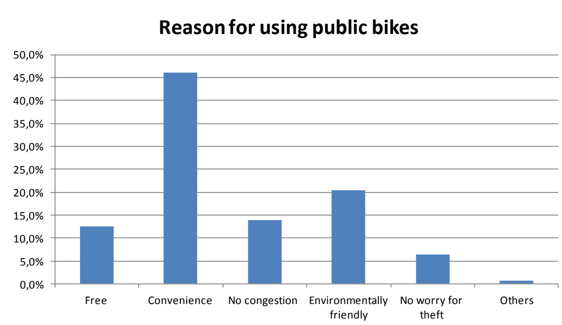


Figure 6. Purposes & reasons for using public bikes.

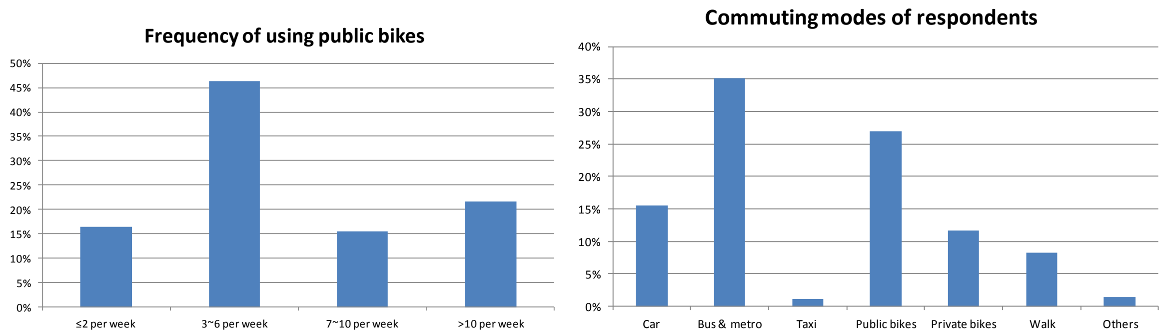


Figure 7. Frequency of using public bikes and its share as the commuting mode among respondents.

6. IMPACT ASSESSMENT

Based on the results from the questionnaire survey and the transaction data, an impact assessment of the Ningbo system is made in comparison to five other cities as shown in Table 1. The bike sharing system in Ningbo sees trips that are comparably long (in time and distance). Due to the high use frequency (trips per day per bike) and a relatively high car substitution ratio, the system in Ningbo has a much higher impact in terms of kilometre car travel reduction per year per bike. This means that the public bike system in Ningbo has been contributing significantly to the sustainability of the urban transport system of the city.

Table 1. Bike Share Usage and Car Travel Reduction: Ningbo vs. five other cities

City	Melbourne	Brisbane	Washington DC	Minnesota	London	Ningbo
Number of bikes	600	1800	1800	1325	8000	15000
Trips per day per bike	0.6	0.3	3.0	0.9	3.1	3.7
Mean trip duration (min)	22.0	16.2	15.8	17.5	17.5	23.0
Est. distance travelled per trip (km)	4.4	3.2	3.1	3.5	3.5	3.48
Est. total distance travelled per day (km)	1666	1852	17338	2564	86454	194184
Car substitution percentage	19%	21%	7%	19%	2%	16%
Est. car travel reduction per year (km)	115826	142361	444187	182390	632841	11340346
Est. car travel reduction per year per bike (km)	193	79	247	135	79	756

Note: data based on May 2014 for Ningbo and on year 2012 for the other cities (Fishman *et al.*, 2014).

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7. CONCLUDING REMARKS

In this paper we have evaluated the effect of the bike sharing system in Ningbo, China. We have shown that stations exhibit particular rent/return profiles over the day, dependent on the land use pattern of the surrounding areas. Residential areas and business areas show opposite rent/return peaks during the morning/evening rush hours. It is also noted that the rent-return imbalance problem is not very severe and mainly occurs at places of “gathering”.

A questionnaire survey among current users further reveals that people choose public bikes mainly for their convenience and the car substitution ratio is relatively high (16%), while half of current users are previous public transit passengers. This seems to imply that the bike sharing system has more effective in alleviating public transit crowdedness than reducing car travel, although the amount of car travel reduction is also significant. Here it should be noted that the results on impact is based only on the data from May-July 2014. Seasonal effects (e.g. lower usage during winter) and long-term adaptation rate (e.g. curiosity effect /retirement /drop-out, late adopters) should be considered in future analyses.

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