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Research article

Modeling cyclists' facility choice and its application in bike lane usage forecasting

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ABSTRACT

In some circumstances on streets equipped with new bike facilities, cyclists are not interested in using them. Instead, they continue to use shared spaces with pedestrians or motor vehicles. Thus, simply adding a bike facility does not guarantee that cyclists will switch to using it. Owing to the considerable development of bike facilities, the investigation of facility preference, particularly focusing on facility choice forecast, has become increasingly important. This study developed a model for predicting the facility choice of cyclists between on-street facilities (curb, traffic lane, and bike lane (BL)) and off-street facilities (sidewalks). Initially, the optimal model was selected using Bayesian Model Averaging method. Then, it was validated by both internal and external validations. Apart from the aforementioned factors, several other exogenous variables were also found to be significant predictors of bike facility choice, including the width of traffic lanes, existence of real-time stopping vehicle, type of bike, bus stop existence, and in-group cycling. Analysis of the relative importance of predictors indicated that bus stop existence, effective sidewalk width, and type of bike were the potential predictors. A framework for predicting BL usage, if it is present, was also developed. A test for the predictive performance of the application at a real site was carried out. By comparing predicted and actual BL usage figures, the analysis showed good predictive performance. The results of this study can help developers, planners, and designers to adopt reasonable investment decisions as well as better designs in developing new bike facilities.

1. Introduction

Because of some excellent advantages of cycling such as being environmentally friendly, good for public health, and affordable, many policies have been introduced to improve bicycle ridership in many cities. Therefore, bike facility development is considered as a key step. In fact, bike facilities have been widely developed in recent decades and the bike lane (BL) is one of the most popular facilities. In general, cyclists show high preference to BLs (e.g. [1,2–4]). However, in some instances, cyclists are diverted from the BLs, as is the case in San Francisco [5] and Texas [6,7]. This can be viewed as a significant wastage of resources.

Analyzing facility preferences among cyclists plays an important part in avoiding ineffective bike facilities. Unsurprisingly, there have been many studies focused on this issue. Previous studies have indicated some factors that can affect the attractiveness of bicycle facilities in general and BLs in particular. These factors can be roughly categorized in three groups as follows.

First, regarding factors related to infrastructure condition, cyclists often show great preference to bike-only facilities over shared ones [8,9]. In terms of BL, their attractiveness is often compared to sidewalks because in the street, cyclists are often allowed to choose either of them. Previous studies showed a mixed trend about this. For example, from the investigation of BL attractiveness in many cities, Dill and Carr [10] found that BLs are generally preferred by cyclists, however, in the study of Aultman-Hall and Adams Jr. [11], in examining facility preference in major roads in Ottawa and Toronto, Canada, they found that sidewalks were used more frequently. Other infrastructure-related factors such as width of facility, presence of bus stops [12], street function [13], and parking facilities [14–16] can also affect cyclists' facility preference.

Second, traffic-condition factors often impact cyclists' safety perceptions, and therefore affect their facility preference [8,9]. High traffic volume can negatively affect the perceived safety and comfort of on-street riders [12,17]. That could be a key reason why on busy streets, cyclists prefer off-street facilities (e.g. sidewalks, bike tracks) to on-street facilities (e.g. BL, curb lane) [9,11]. Pedestrians, on the other hand, can also make sidewalk riders feel unsafe and uncomfortable [9]. That might reduce attractiveness of sidewalks, therefore increasing the probability that cyclists choose on-street facilities.

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Additionally, factors related to cyclist characteristics also showed correlation with facility preference. For example, gender [1,18,19], age [20] and cycling experience [7] showed significant correlation with their facility preference. While women and inexperienced cyclists prefer off-street facilities, men and experienced cyclists showed the opposite trend [1,18–22]. In terms of cyclist's age, whereas the positive correlation between on-street facility preference and cyclist's age was found in two studies [20,23], Aultman-Hall and Adams Jr. [11] indicated that older cyclists travel relatively more on paths than on roads.

In the quantitative literature, several models have been developed to explain facility preference of cyclists as follows:

Tilahun et al. [8] evaluated individual preferences in five different cycling environments (off-road facilities, BLs with and without parking, in-traffic facilities with and without parking) by trading off a better facility with a higher travel time against a less attractive facility at a lower travel time. The results showed that users were willing to pay the highest price for designed BLs, followed by the absence of parking, then off-road facilities. Age, gender, and household size were also significant predictors for cyclists' facility preference.

Stinson and Bhat [14] investigated the importance of factors affecting commuter bicyclists' route choices based on equipped facilities' characteristics and traffic conditions. They developed empirical models, which indicated that travel time was the most important factor in choosing a route. Presence of a bicycle facility (especially a BL or separate path), the level of automobile traffic, pavement or riding surface quality, and presence of bicycle facilities on bridges were also very important determinants.

Taylor and Mahmassani [6] used a stated preference survey to seek for "bike and ride" options. A nested logit choice model was developed. The results indicated that BLs were superior to wide curb lanes as an incentive for casual and inexperienced cyclists, but that BLs and wide curb lanes are an identical incentive for experienced cyclists.

Abraham et al. [24] investigated cyclist preference regarding different attributes of alternate routes. Respondents were asked to rank the alternatives among three alternate routes based on their attributes (e.g. facility type, traffic condition). A logit choice model was developed for analyzing the responses. Among independent variables of interest, off-street cycling facilities and low traffic residential streets were preferred by the respondents.

As can be seen, these models were developed to seek facility preference trends of cyclists rather than predicting facility choice in general and BL in particular. There was no study focusing on predictive performance of the model in practice. These models, on the other hand, also did not consider a wide range of independent variables, which can affect facility preference of cyclists as reviewed above. Although predictive performance in practice of these models was not mentioned, it is difficult to achieve good performance because of the lack of predictor-coverage fulfillment.

So, this study aimed to develop a model for predicting facility choice between on-street facilities (curbs, traffic lanes and BLs) and off-street facilities (sidewalks) of cyclists in daily cycling practice environments, then, a framework for predicting BL usage if it is present in certain street conditions was also developed. Eighteen independent variables belonging to three factor groups (infrastructure, traffic condition, and cyclist characteristic) were considered. Apart from the aforementioned factors such as width of facilities, vehicle volume, age and gender, several exogenous factors such as existence of barriers between the sidewalk and carriageway, bus stop presence, existence of real-time stopping vehicles, presence of waiting vehicles, type of bicycle, cyclists cycling in a group, and number of passengers on the bicycle were also investigated in this study. Results of this study can help developers, planners, designers, etc. adopt more reasonable investment decision as well as better design in developing new bike facilities.

2. Methods

2.1. Sites and surveys

This study investigated three factor groups: infrastructure, traffic condition, and cyclist characteristic. While the infrastructure information was collected by on-site observations and measurements, the data on traffic conditions and cyclist characteristics were collected by computer-based processing of the videos, which were recorded on the streets.

Fifteen urban street segments (sites) were surveyed within two years 2013–2014. All sites are located in Saitama city, Japan. Training data (for developing the model) was collected at 14 sites (No.01–No.14) of which, six sites had BLs and the other eight sites did not. Each of these sites was surveyed one time in one day. Site No.15 was surveyed two times (in two days), before and after implementing the BL. Data for site No.15 (external data) was used for external validation and testing the model application in predicting BL usage after implementing it. Fig. 1 shows the positions of the fifteen surveyed sites.

All selected sites had a typical cross-section of a medium size urban street with 2 or 3 traffic lanes, where trucks were prohibited in these streets, two sidewalks on both sides of the street, and both on-street and off-street facilities were available for cyclists to choose a route freely. The BLs in these sites were not implemented at the same time when the streets were built. Instead, they were added in several recent years in the form of a blue-painted striped lane. According to Japanese guideline [25], in the database, we actually had two types of BL: "real" and "non-real" ones. A real BL must satisfy two conditions: (1) its width must be greater than or equal to 1.0 m and (2), there must be a traffic sign on the street showing that there is a BL. According to Japanese traffic law [26], only cyclists are allowed to use the real BL. The non-real BLs in this study, although in the form of blue stripes, were smaller than 1.0 m. The blue stripe guides cyclists that they should use this space. Other road users can also use the space but the blue stripe may alert them about the danger of a cyclist existence, and they should give priority to cyclists. In this study, to make it simple, we did not distinguish these two types. Instead, all of them are so-called "bike lane" ("BL"). Fig. 2 shows images of typical with- and without-BL sites.

While determining infrastructure features, the measurements of each site were carried out within a "segment." A segment in this study refers to a part of the street between two intersections, where infrastructure condition is relatively constant throughout its length, and the design of both ends of these segments must allow cyclists to choose between on- and off-street facilities freely. In all selected sites, the sidewalks were physically separated from the carriageway by a curb, fence or green stripe, so cyclists were unable or it was made very difficult to change between on- and off-street facilities along the segment.

The camera setup was based on the following factors: (1) It could observe cyclists clearly while they were riding either on- or off-street. (2) The recording direction was set so as to see the face of the cyclists riding on their left side (legal side in Japan), while cyclists who rode in the opposite direction were excluded from the data set. (3) Motor vehicles on the nearest lane to the surveyed sidewalk (where the camera was set) had to be observed. (4) The camera covered at least a 40 m length of the observed segment.

2.2. Data extraction

In total, 1958 cyclists were investigated in this study, of which, training data (site No.01–No.14) and external data (site No.15) had 1402 and 556 cyclists respectively. In external data, the sample sizes of before and after implementing BL data were 308 and 248 respectively.

Although the surveys started around 7:30 a.m., data extraction started in real-time at 8:00 a.m. and ending time ranging from 10:00 a.m. to 12:00 p.m. Time duration of each site depended on its' cyclist volume. If cyclist volume were high, the time duration would be

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