Analysis of Bicycle Passing Events for LOS Evaluation on Physically Separated Bicycle Roadways in China

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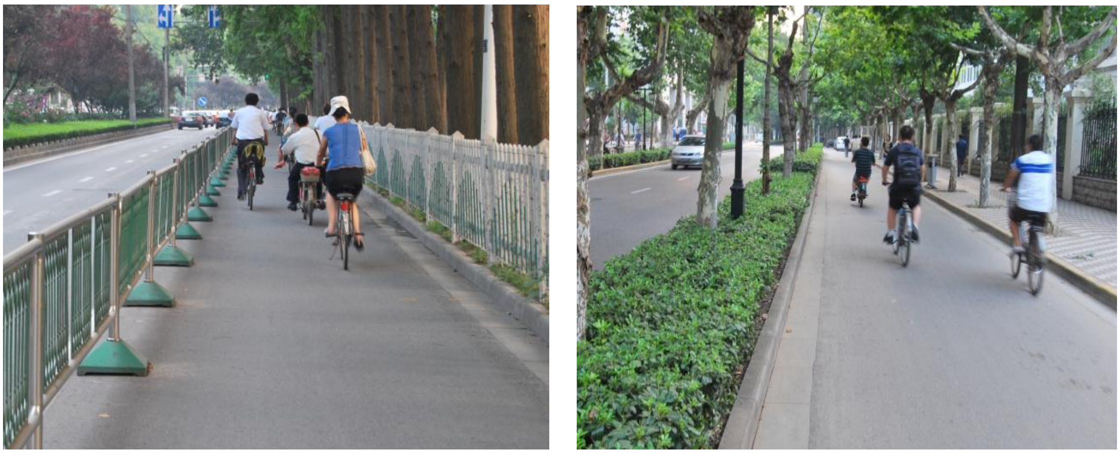
ABSTRACT

Bicycle contributes 30% to 70% of daily trips in China. Bicycles have their own bicycle lanes built to the right of the motor lanes for each direction of traffic in most cities in China, physically separated from vehicles and pedestrians. Nowadays, they are becoming increasingly busy in many cities. Transportation authorities have been trying to build new or expand existing bicycle roadways to increase bicycle capacity. However, they are in lack of quantitative bicycle Level of Service (LOS) analysis tools designed and calibrated for conditions in China. This paper introduces a LOS evaluation method based on the estimation of the indicator, the number of passing events, according to the bicycle flow characteristics. In our study, the passing events, which was found to be a good indicator of bicycle user's comfort in early literatures, can be classified into free passing events, adjacent passing events and delayed passing events, on physically separated bicycle roadways. Models are built to calculate the number of three kinds of events. Passing events data are collected from two physically separated bicycle roadways using random bicycle-following method. Fitted relationships of the field data and the model prediction are compared, and the proposed model is found to be able to effectively estimate the number of passing events. Sensitivity of some key parameters in the model and potential application of the proposed model are also discussed in the end.

1 INTRODUCTION

In China, bicycle is the most common-used mode of transportation which accounts for about 30% to 70% of all trips in most cities (*1*).Physically separated bicycle roadways are paved, on-street, unidirectional travel ways designed to serve bicycle travelers, on which bicycle traffic is separated from motor vehicles and pedestrians by a barrier or a separation strip, just as Figure 1 shows.

Across cities in China, physically separated bicycle roadways are the most common facilities for bicycles. They are becoming more and more popular in recent years in China for two reasons. First, for mobility, unseparated bicycle traffic can seriously disturb the motor vehicle traffic or disturbed by pedestrians, decrease both motor vehicle and bicycle capacity. Physical separation can solve this problem. Second, for safety, physical separation can reduce the confliction between bicycles and motor vehicles thus it increases the safety of bicyclists and reduces the number of vehicle-bicycle accidents. To improve the capacity of bicycle roadways adapting to the large bicycle volume, most of them are designed from 1m to 5m wide in one direction, with no contraflow bikes, no vehicle parking or blockages in the bike lane, no pedestrians crossing, and few intervening bus stops. Two such segments far from intersections were investigated in this study.



(a) (b)

FIGURE 1 Typical physically separated bicycle roadways in China.

One serious challenge for transportation planners and designers in China is to determine the bicycle level of service, which is critical in choosing the right width of bicycle path in bicycle path construction and expansion projects. At this time, Chinese highway design manuals do not have enough information for such fundamental questions. Only some simple and qualitative suggestions are proposed and some road fractures are recommended (*2*). It does not give specific approaches or guidelines to determine the bicycle level of service and the desired width of bicycle path.

There are various indexes to measure the bicycle level of service. And the prevailing index is the number of events which can effectively reflect the satisfaction rate of a bicycle user. However, the index cannot be used directly for physically separated bicycle roadways. Under such background, our objective is to propose a model suitable for conditions in China so that professionals and designers can use it to evaluate the operational effectiveness of physically separated bicycle roadways. The rest of the paper is organized as the following. In the next section, previous literatures on bicycle LOS are reviewed. Then the proposed methodology is described in details in section 3. Section 4 describes our data collection procedure and the results. And in section 5, further discussion on sensitivity analysis and potential application of the model is conducted. Finally, in section 6, conclusions are drawn.

2 LITERATURE REVIEW

Previously, many methods to evaluate bicycle LOS have been investigated by not only researchers from academic but also planners from transportation agencies, Metropolitan Planning Organizations (MPOs) and etc. However, the most influential works are done by Botma, Landis, Davis, Sorton, Epperson, and Harkey, et.al.. Botma (1995) set up a procedure for determining bicyclist LOS on the concept of the hindrance experienced by path users (*3*). The more disturbing events a bicyclist meets, the higher obstruction he suffers and the less comfortable the trip is. Based on field studies conducted in the Netherlands, LOS is set up on the perceived hindrance to users, as a function of pedestrian and bicyclist volumes, path width, and speeds (*4*). The 2000 Highway Capacity Manual (HCM) adopted the Botma's procedure (*5*). Hummer (2006) studied the number of events happened on mix bicycle and pedestrian roadway and modified the HCM 2000 procedure (*6*). Landis, B. W. (1994) first described a theoretical model to estimate bicyclists' perception of the hazards of sharing roadway segments with motor vehicles (*7*), then Landis (1996) described the development of a *Bicycle Level of Service* (BLOS) based on human responses to measurable roadway traffic stimuli (*8*). Harkey, D. (1998) proposed a methodology to determine the compatibility of a roadway in efficient handling both bicycles and motor vehicles (*9*). The proposed *Bicycle Compatibility Index* (BCI) can evaluate the bicycle friendliness of a roadway by measuring the geometric and operational characteristics roadways. Sorton, Alex (1994) developed a bicycle stress level measure to evaluate the suitability of roadway facilities for bicycling (*10*). Researchers at Northwestern University (1994) assigned stress levels between 1 and 5 to three primary factors and to three secondary factors that contribute to the relative attractiveness of bicycle facilities (*11*). Epperson, Bruce (1994) studied the level of Service indicators to evaluate suitability of roadways for bicycle use and discussed factors to be considered in future refinement of such indicators (*12*). Density of bicycle has often been proposed as a measure of effectiveness (MOE) for bicycle facilities. Previous studies in California (*13*), Germany (*14*), and China (*15*) all proposed levels of service based on density.

From the above, we can see that although many researchers have studied on bicycle LOS, most of them only proposed qualitative guidelines. Some researches provide LOS scales but the scale classification is too arbitrary without clear differences between one scale to another, such as density and stress level. Others emphasize on the influence of environment (the motor vehicle flow, street parking or pavement conditions, etc.) too much, such as BLOS and BCI. As for the evaluation of bicycle LOS on bicycle roadways, Botma's procedure remains the best because of its quantitative and qualitative features in LOS scale classification. Moreover, because the bicycle flow rate is relatively high in China, disturbing events are quite frequent and different types of disturbing events can all be observed. Therefore it is suitable to use the number of events to evaluate the comfort degree of physically separated bicycle roadways in China. Botma (1995) suggested disturbing events of bicycle can be divided into passing events and meeting events. Passing events refers to the situation where the bicyclist desires to pass slow-moving bicycles on the path, while meeting events refer to the number of opposing vehicles that are met while the average bicyclist is on the path. Hummer (2006) further pointed out that passing events can be divided into active passing events and passive passing events. The reason to include passive passing events is that such events also interfere with other riders. The concept of "delayed passing events" was also proposed. They happened when a bicycle cannot overtake because all lanes in the same direction and the opposite direction are occupied. However, in order to use Botma and Hummer's models in different countries, they should be modified and calibrated. In this paper, we re-developed and calibrated a new LOS evaluation model using bicycle passing events for physically separated bicycle roadways in China, or other roadways with the similar traffic conditions.

3 METHODS

3.1 Conditions and Characteristics

Botma and Hummer's methods are based on bicycle roadway conditions in Netherlands and America. In order to use them in Chinese physically separated bicycle roadways, modifications shown below are made based on the special conditions and characteristics of such roadways in China.

First, in previous model, pure bicycle roadways are generally bi-directional and consist of two or three lanes divided by lane markings. While the typical physically separated bicycle roadways in China are one-way with multi-lane. As a result, there is no need to keep the meeting events which concerns the opposing bicycle traffic. And the interactions between bicycles and vehicles or pedestrians are also not taken into account due to the physical separation.

Second, the bicycle roadways in Botma and Hummer's research are usually narrow and all the overtaking or being overtaken events are supposed to have a severe influence on the bicyclists in their model. While Chinese separated bicycle roadways can be large width such as unidirectional three lanes or four lanes. When overtaking happens between two bicycles more than one meter apart, the overtaking has very little impact on the comfort of bicyclists. Moreover, the total active passing events equal the passive ones. Consequently, this paper mainly studies the active passing events putting aside the passive passing events which may still have some impact and will be part of the future study.

Third, Hummer (2006) assumes that the delayed events in the same direction are caused by two bicycles running in company or the passing events in the opposite direction occupying the lanes. But on the physically separated lane in China, delayed events primarily occur in bicycle flows of big volume and high density (about 95% comparing with 5% for Hummer's assumed situation based on field observations) due to the wider total path width. The primary key variables to investigate the delayed passing events in our study are flow and occupancy.

Last, there are other differences such as the separation form, trip purpose (primarily commuting trips in China) and the performance of bicycles. They all lead to the differences of bicycle riding behavior. But these differences can be captured in the characteristics of some basic flow variables (such as average speed, speed variance).

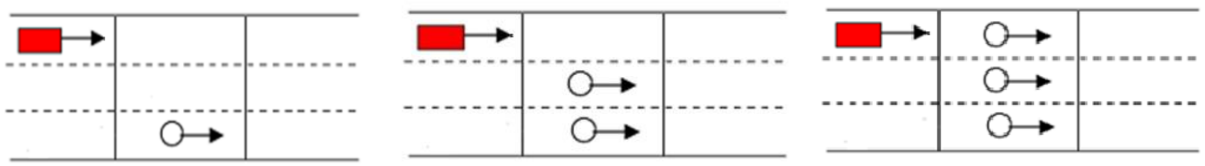
3.2 Classification of Passing Events

Considering the above analysis, we shall propose a new classification system for events mentioned in Botma and Hummer's model. In our research, passing events can be classified into three types of events. The followings are the explanation of each type of events and how they are counted for the bicycle LOS evaluation (Also see Figure 2 for graphical illustration):

Free passing events: When overtaking happens, the horizontal distance of free space between overtaker and overtakee is more than the width of one lane. Such events will only slightly or almost not impact the comfort of both bicyclists.

Adjacent passing events: If the horizontal spacing of free space is only enough for one bicycle to pass through, namely the overtaker and overtake are on the adjacent lanes, such passing events have more severe impact on both bicyclist's comfort level because overtakers have to concentrate on maneuvering their bicycles.

Delayed passing events: If the horizontal spacing of free space is not enough for one bicycle to pass through. In this case, the bicyclist trying to overtake needs slow down to the speed of front bicycles to wait for the overtaking opportunity. In this situation, the overtaker are forced to decelerate or accelerate, costing physical energy, so it will cause serious discomfort.



(a) Free passing events (b) Adjacent passing events (c) Delayed passing events

Subject bicycle ○ Other users

FIGURE 2 Types of passing events on a three-lane path.

Note that we assume overtaker only affects the overtakee at the adjacent lane, so if there are other bicyclists parallel to the overtakee, the event count will still be one. Obviously the influence levels of different kinds of events to bicyclists are different, but they are not studied deeply here.

3.3 Model Development

In this section, the probability formulation of each kind of passing events is proposed based on the occurring conditions, and the model of total number of events is established. Then the number of each kind of passing events can be easily calculated.

3.3.1 *Glossary of Assumptions and Variables*

Except for conditions mentioned in Section 3.1, the followings are some additional assumptions about bicycle traffic and passing events that facilitate model development:

1. The speeds of bicycles are normally distributed, which was verified with field data collected (*1*, *6*).

2. When no passing events occur, bicyclists ride on random bicycle lanes, which is in accordance to the Chinese traffic conditions.

3. Slower bicycles will keep to the right as passing events need to occur, because the overtakers would ring to ahead bicyclists to enforce them to ride to the right lanes.

Notation list to be used in the coming derivations are as follows:

L = length of path, km

Q = bicycle flow rate, veh/h

v = bicycle speed, km/h

μ = bicycle mean speed, km/h

σ = bicycle standard deviation of speed, km/h
k = bicycle density, veh/km ·lane
n = number of bicycle lanes
v^* = speed of the test unit, km/h
d = length of cell, m
n_{occ} = number of lanes be occupied
$n_{no\text{-}occ}$ = number of lanes not be occupied
P_{free} = probability of free passing events
$P_{adjacent}$ = probability of adjacent passing events
$P_{delayed}$ = probability of delayed passing events

3.3.2 *Division of Lane Cell*

The proposed methodology uses the bicycle variation of cellular automation (CA) model (*16*, *17*). Each bicycle lane segment is divided into minimal cells. In a CA model for traffic flow, each cell represents a discrete section of the roadway of a specified distance. Suppose that in any given time step, all the bicycles are running in cells, and each cell may either be occupied or not. Gregory Gould (2009) set 7 feet (2.1 m) as the length of bicycle cellular (*18*), while Zhang Jin (2006) and Li Yanxia (2008) adopted two meters as the length of bicycle cellular for China (*19*, 20). And this paper also adopts two meters as the length of bicycle cellular to divide the segments into several cellulars as Figure 3 shows.

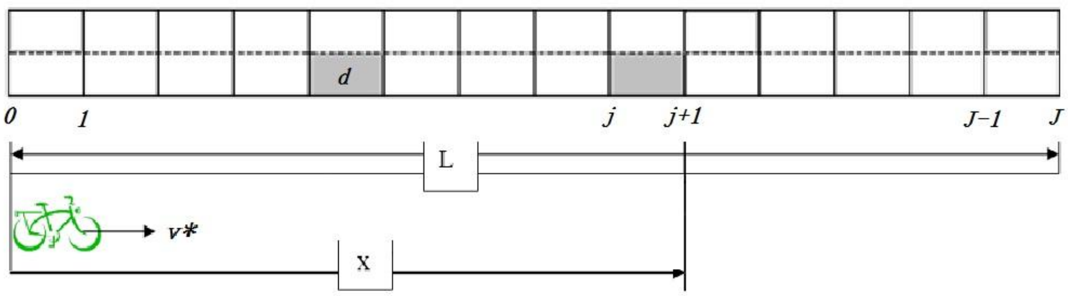


FIGURE 3 Schematic diagram of minimal cells on bicycles lanes.

The minimal space headway of each bicycle within the bicycle lane is two meters. Then the maximal density is K = 500 (veh / km ·lane). Divide the bicycle lane into J sections according to cell length as Figure 3 shows and $J=L/2$.According to assumption 2, the probability that one cell is occupied for one lane in length L with a density of k is $p_{occ} = k / K$. We also assume that for strip [j, $j+1$], the probabilities that each lane is occupied are equal and the occupancy of each lane is relatively independent. Then within the strip [j, j+1], the number of occupied lanes obeys the *Binomial bernoulli distribution*, designate it as $n_{occ} \sim b(n, p_{occ})$:

$$P\left(n_{occ} = x\right) = C_n^x \cdot p_{occ}^x \cdot (1 - p_{occ})^{n-x} \quad x = 0, 1, 2, \cdots, n \tag{1}$$

Then probability of the unoccupied lanes $n_{no\text{-}occ}$ is:

$$P\ (n_{no\text{-}occ} = x') = P\ (n_{occ} = n - x') \tag{2}$$

3.3.3 *Occurring Conditions of Passing Events*

When the passing events happen, three kinds of events may occur as defined in the above section. When the number of lanes $n \geq 2$, and the test bicycle arrives in the front of strip [j, $j+1$] with the speed v^*, as Figure 3 shows, three kinds of events occur under the following conditions. These conditions including the number of occupied lane constraints, speed constraints. Note that these conditions are based on the assumption 3 that slower bicycles are kept to run to the right when events occur.

Free passing events occur when:

- within [j, $j+1$] unoccupied lanes are more than or equal to 2;
- within [j, $j+1$] unoccupied lanes are equal to 1 and at least one bicycle's speed is faster than v^* within the occupied lanes;
- within [j, $j+1$] all lanes are occupied, but at least two bicycles' speeds are faster than v^*;

Adjacent passing events occur when:

- within [j, $j+1$] unoccupied lanes are equal to 1 and all bicycles' speeds are less than v*;
- within [j, $j+1$] all lanes are occupied, but only one bicycle's speed is faster than v*, the speed of the rest are less than v*;

Delayed passing events occur when:

- within [j, $j+1$] all lanes are occupied and all bicycles' speeds are less than v^*;

Suppose the speed of bicycles on the segment follows normal distribution with $N(\mu, \sigma^2)$. The average speed μ and variance σ can be obtained through surveys and the probability $P(v \leqslant v^*)$ can be easily get through the integral under the standard normal curve. Then:

$$P(v>v^*)=1-P(v\leqslant v^*) \tag{3}$$

On all conditions that the numbers of lanes are larger than 2, the probability of each passing events can be similarly calculated using occurring conditions and equation 1, 2 and 3. Here is no need to list them.

So the number of each kind of events within the segment L can be calculated through the formula below.

$$E_{free} = P_{free} \cdot E_{total} \tag{4}$$

$$E_{adjacent} = P_{adjacent} \cdot E_{total} \tag{5}$$

$$E_{delayed} = P_{delayed} \cdot E_{total} \tag{6}$$

Where, E_{total} is the total number of passing events, assuming that the path has adequate width, so that no passing or other events are constrained by the path geometry. Computational progress is shown in the following section.

3.3.4 *Estimating Total Number of Passing Events*

Suppose the test bicycle is traveling at a constant speed v^*. This situation is depicted graphically in figure 3 as shown above. Let x be the distance from the location of the test bicycle to a strip [j, $j+1$] on the path of length d, so $x = (j+1) \cdot d$. So the expected number of bicycles in d is $k\ d$. The test bicycle will pass only those units in d that will exit the segment L after the test bicycle has exited. Mathematically, the probability that test unit passes the bicycles at the point x within the strip [j, $j+1$] is defined as:

$$P_{j,j+1}(v^*, x) = P\,[(L-x)/v > L/v^*] = P\,[v < v^*(1 - x/L)] \tag{7}$$

Therefore, the total number of passing events for strip [j, $j+1$] will be:

$$E_{j,j+1}(v^*, x) = n \cdot k \cdot d \cdot P\,[v < v^*(1 - x/L)] \tag{8}$$

Since v is distributed with $N(\mu,\sigma 2)$, then the probability in equation 8 can be easily calculated from the integral under the standard normal curve. By numerically repeating this process for $x = 0$ to L in increments of d, the total number of passing events on the path can be estimated.

The above probability formulation is quite sensitive that a passing event is considered to be possible even when the absolute speed differences between the test unit and slower moving units ahead of it are quite small. This assumption can be relaxed by using the ratio of the speed of the overtakee to overtaker vehicle (*6*). When the ratio exceeds the a pre-defined threshold β, a passing event can be triggered. In this case, the probability of passing described in equation (8) can be rewrote as:

$$P_{j,j+1}\,(v^*, x) = P\,[v < min\,(\beta v^*, v^*(1 - x/L))] \quad (9)$$

When $\beta = 1$, the number of passing events estimated by equation 9 reverts to the original formulation in equation 8. A beta threshold of 0.80 means that a passing event occurs only if the speed of overtakee bicycle is below 80 percent of the overtaker's speed.

4 DATA COLLECTION AND RESULT ANALYSIS

4.1 Data Collection and Statistics Analysis

To inspect and verify the fitted relationships between the model prediction and field data on actual segments and to acquire the actual parameters of bicycle flow, a survey was conducted on Tuesday, October 17, 2006 in Nanjing, Jiangsu, China. The weather was sunny and warm. 42 students from Transportation School of Southeast University were trained to participate in the survey and the survey time was from 7:00 am to 9:00 am which is the morning peak period in Nanjing. The carefully-selected segments locate in the central district of Nanjing. They are all physically separated and there is no street parking and the range of visibility is well. The survey content is divided into the following aspects: path information, bicycle flow characteristics (flow rate, speed and the density), and the number of passing events.

The team collected speeds of the bicycles by using a stopwatch on clearly marked fixed-length segments at both sites. Bicycle flow rate was measured through the number of bicycles passing through a roadway cross-section. The whole sections were photographed to get the density of the non-motorized vehicles. The path information and characteristics of bicycle flow on each path is collected as Table 1 shows:

TABLE 1 Statistics of Path Information and Characteristics of Bicycle Flow

Path Number	No.1	No.2
Path Information		
Path name	Danfeng ST	East Beijing Road
Path direction	From North to South	From South to North
Separation form	Physically Separated	Physically Separated
Separation pattern	Barrier	Border
Width (m)	2.6	3.5
Number of Lanes*	2	3
Surface condition	Concrete Pavement	Asphalt Pavement
Study Length (m)	260	450
Horizontal Curvature	No	No
Vertical Curvature	Low	No

Characteristics of Bicycle Flow		
Sample Size	87	74
Average Speed (Km/h)	14.58	12.59
Speed Variance (Km/h)	3.78	3.36
Average Density (veh/km·lane)	73.6	70.3

** Conversion relations between width and the number of lanes is from AASHTO (21)*

4.2 Passing Events Analysis

Random bicycle-following method is used to investigate the bicycle events on each segment. In this method, a member of the survey team rides a bicycle, randomly chooses a bicyclist to be respondent and records the events he encounters by following the respondent's travelling trace on the surveyed segments. Due to the difficulty of observing all events, this survey only investigated the adjacent passing events. Free passing events and delayed passing events were not recorded.

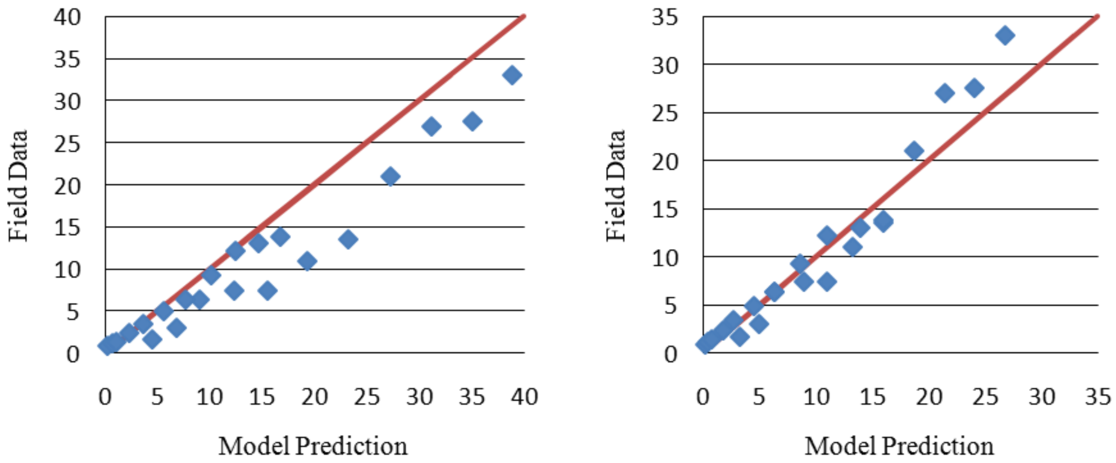
The major purpose of the operational data collection was to validate the model developed in chapter 3 by comparing the measured number of passing events against that predicted number from the model. Table 2 shows a summary of the passing-event data in terms of average values per length.

TABLE 2 Summaries of Field Data of Adjacent Passing Events

*v** (km/h)	Average Number of Events (veh/km)	
	Path 1	Path 2
8~10	–	0. 9
10~12	1.7	1.4
12~14	6.4	3.5
14~16	8.5	6.4
16~18	13.5	12.2
18~20	25.9	13. 8
20~22	29.2	–
Average flow rate (veh/h)	2145	2655

–: Data investigated but no results

Figure 4 shows the fitted relationships between the predicted values from the model and the real data. Figure 4a shows the fitted relationships at the confidence level $\beta=1$ and it is shown that the overall trend is quite consistent, but the predicted values are generally bigger than field values. This is primarily because that when $\beta=1$, the triggering condition of a overtaking becomes the same as using the absolute difference condition (See Equation 9). And a very small speed difference can lead to passing events in the model. However, when the confidence level $\beta=0.8$ (see Figure 4b), it is observed that the model prediction is quite accurate compared with the surveyed data. Therefore, we can make a preliminary conclusion that the proposed model can accurately describe the event's frequency on actual segments.



(a) Threshold $\beta = 1$ (b) Threshold $\beta = 0.8$

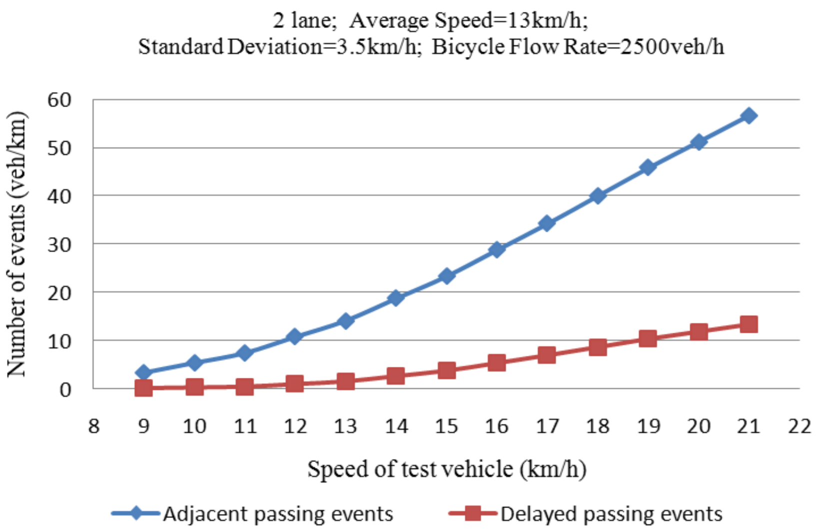
FIGURE 4 Fitted relationships between model prediction and field data.

5 DISCUSSIONS

5.1 Sensitivity to Key Parameters

This section discusses the sensitivity of some key parameters in the prediction model of the number of passing events. The speed and the directional flow rate were allowed to vary while keeping all other parameters fixed on the two bicycle paths. These analyses are important as the first step in understanding the characteristics of the proposed passing events model.

In our study, *Microsoft Visual C++ 6.0* (*SP6*) is used to program the calculation algorithm for the number of events. The computing results are summarized in Figure 5 and Figure 6.



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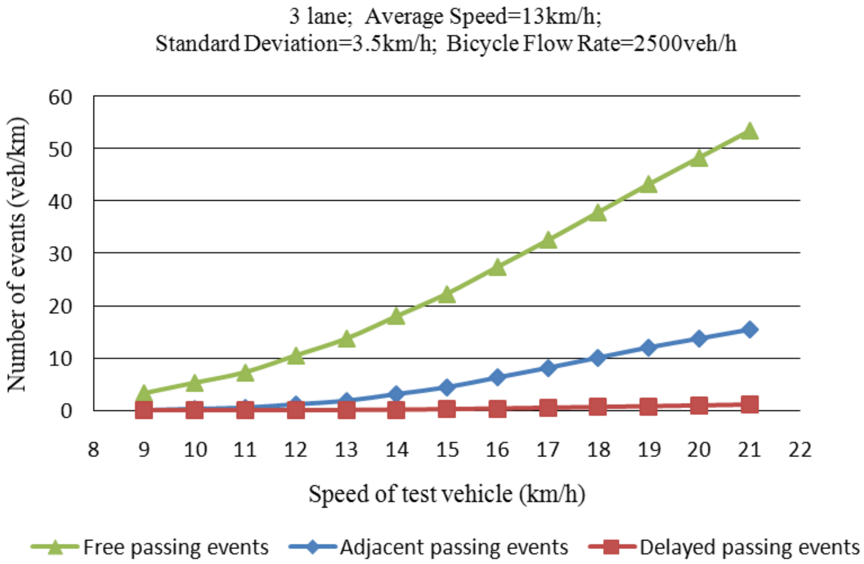
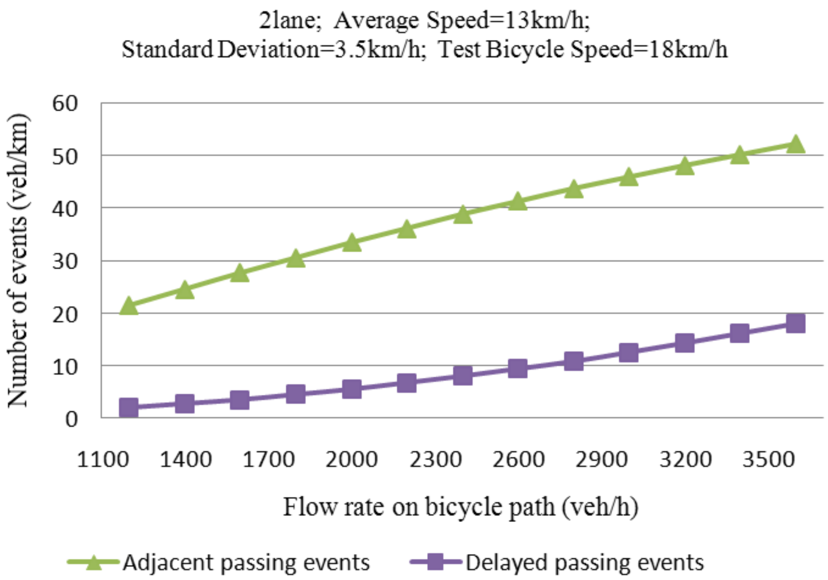


(b)

FIGURE 5 Sensitivity of passing events to test bicycle speed.



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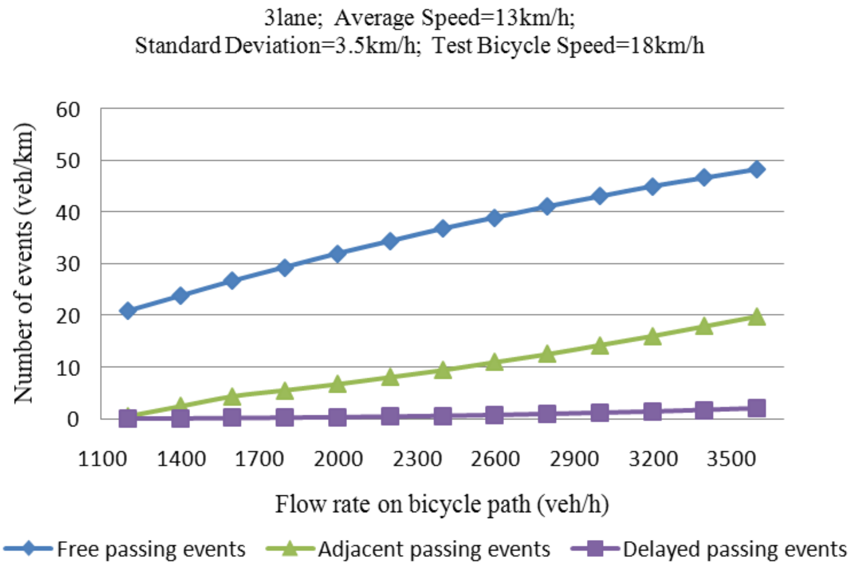

(b)

FIGURE 6 Sensitivity of passing events to bicycle flow rate.

From the Figure 5 it can be seen that just as expected, with the increasing of test bicycle's speed, the events (free or adjacent or delayed events) are increasing and the frequency of adjacent events are more than that of delayed events. It illustrates that the faster a bicycle runs, the more events he suffers. Figure 6 proclaims that the number of three kinds of events all increase with the increase of bicycle flow rate. This coincides with expectation, which can show the proposed model can be used to estimate the operational state of bicycles on physically separated bicycle roadways. From the comparison of each type of passing events on two-lane or three-lane segments in the two figures above, it is easy to see that the sums of all events do not show big difference. But most of the events on three-lane segments are free events which have little influence on the bicyclists. The frequency of adjacent events and delayed events on two-lane segments is much bigger than that on three-lane segments, and both of those two events can cause large disturbance to bicyclists. Therefore, the increase of the number of lanes (or the path width) can relieve of the interaction of bicyclists and increase the LOS.

The model established in this paper also shows that the increase of the speed variance can result in more passing events. In recent years more and more electric bicycles take over the bicycle lanes together with traditional bicycles in China and their speed is higher than that of average bicycles, which makes the discreteness higher and causes more passing events.

5.2 Applications of Proposed Estimation Model

There are two major advantages of the proposed model. The first one is that it provides a uniform quantitative measurement. And the other one is that the key factors of the model such as flow rate and lane width are easy to measure through field surveys. Meanwhile, the classification of the passing events and the establishment of model introduced in this paper can benefit future research on the quantification of bicycle user comfort and it can be an important index to measure and divide the level of service. It is especially useful for bicycle trail planning and designing tasks that need to have quantitative measures for decision making such types of decisions including the followings:

• Planning of appropriate widths and cross sections for new bicycle trails.

• Evaluation of the bicycle LOS provided on existing trails.

• Design of improvements for existing trails.

• Determination of how many additional users a trail can serve given a minimum LOS threshold.

• Determination of the LOS at a particular location on a trail, such as a narrow pinch point, in an unusually high-use area, or in an area with many reported user conflicts.

6 CONCLUTIONS AND FUTURE STUDY

The overall project objective is to propose a tool that transportation professionals can use to evaluate the operational effectiveness of physically separated bicycle roadways, when given traffic forecasts or observations at an existing path along with some geometric parameters. The proposed model adopted Botma's framework for bicycle LOS evaluation, however, major modifications are conducted so that the model can be applied to the urban bicycle traffic conditions in China. In this research, except for the proposal of the new model, there are two other highlights. First, based on the overtaking conditions for various passing events, we classified the passing events into free passing events, adjacent passing events and delayed passing events. Second, our team developed a method to calculate the probability of the three types of passing events.

In order to test the model, two physically separated segments in Nanjing were surveyed. The field data were compared with the prediction of our proposed model and the results showed that the prediction matched the field data fairly well at both test sites. Sensitivities of key parameters that influence the number of passing events are also analyzed. And recommendations on the application of the proposed model for the designers and planners of policies are given.

Admittedly, there are also some limitations to our model and some future studies are necessary.

1. Due to resource limitations, only two segments are surveyed in this study and the model has not been tested in a large scale. The sample size should be increased and roadways with other widths should also be surveyed and analyzed.

2. Passing events on bicycle trails separated by lane marking and with mixed bicycle and pedestrian are not studied in this paper and should be studied in future.

3. Passive passing events are not considered in this paper, which may also have certain influence on bicyclists.

4. Research should be done about the scaling of bicycle LOS based on the number of passing events for Chinese conditions.

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