AN ANALYSIS OF TRAFFIC CONFLICT PHENOMENON OF BICYCLES USING SPACE OCCUPANCY INDEX

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Abstract: Since bicycle traffic is not sufficiently considered in road planning processes, at present, the road space for bicycle traffic is not serviced sufficiently on many roads. It is necessary to develop evaluation indices of the dangers of bicycle traffic, in order to determine the appropriate road space required for bicycle traffic responding to road and traffic conditions. In the present study, the traffic conflict phenomenon of bicycle traffic is analyzed. Space occupancy indices are applied to the analysis. Throughout the analysis, the applicability of the traffic conflict indices to the phenomenon of bicycle traffic is examined.

Key Words: Bicycle traffic, Traffic conflict phenomenon, Space occupancy

1. INTRODUCTION

In recent years, bicycles have come to be used as an urban transportation mode. However, currently in Japan, the space for bicycle traffic is not sufficient on many roads. On a number of roads, bicycles must use part of the road space that is designed for other transportation modes such as vehicles or pedestrians.

Bicycle use on the walkway is permitted on many roads in Japan. However, particularly on roads with heavy bicycle traffic, mixed traffic of bicycles and pedestrians creates dangerous conditions for both bicycles and pedestrians. It is necessary to provide sufficient space for bicycle traffic in order to solve these problems. However, realistically, it is difficult to provide sufficient space for bicycle traffic on all roads.

Therefore, it is necessary to clarify the danger of mixed bicycle and pedestrian traffic quantitatively. A road space having a reasonable available size must be reviewed to provide an appropriate space for bicycle traffic that corresponds to the traffic demands of bicycles and pedestrians. Therefore, quantitative evaluation indices of the dangers of mixed traffic of bicycles and pedestrians based on traffic conditions are needed.

In many countries, bicycles use on the roadway mainly. Therefore, most of the previous researches on the bicycle traffic focus the characteristics of bicycle traffic on the roadway and mixed traffic with motor vehicles. There are few researches on the characteristics of bicycle traffic on the walkway and mixed traffic with pedestrians. An interview survey is performed for the cyclists and the characteristics of bicycle traffic on the walkway are analyzed (Harland et al., 1986). Level of service index on the pedestrian-bicycle paths is proposed based on the avoidance behaviors of bicycles (Botma, 1995).
On the other hands, most of the researches on the bicycle traffic in Japan are focused on the bicycle traffic on the walkway and mixed traffic with pedestrians. As a conflict analysis of bicycle traffic, the avoidance behaviors of bicycles and pedestrians are distinguished in order to express the conflict phenomenon in previous research. For example, a number of analyses of the relationship between avoidance behaviors of bicycles and pedestrians, road conditions, and traffic conditions have been conducted (Matsumaru et al., 2001; Yamanaka, 2005). The evaluation indices of the traffic conflict are proposed in order to evaluate the service level based on the decrease in the speed of bicycles and the probability of near misses (Yamanaka et al., 2001; Yamanaka et al., 2003). In addition, the TTC (time to collision) index and complicated indices based on the space occupancy of bicycles and pedestrians have been used for conflict analyses (Ogawa et al., 2006; Oshikawa et al., 2004). However, no clear guidelines have been proposed for conflict analyses. Therefore, it is necessary to improve the standard evaluation methods of conflict phenomenon.

In the present study, based on previous research, a conflict phenomenon index based on the space occupancy of bicycles and pedestrians is proposed. The proposed index may be applied to the conflict phenomenon analysis of bicycle traffic and mixed traffic of bicycles and pedestrians in order to verify the applicability of the proposed index.

2. TRAFFIC CONFLICT INDEX USING SPACE OCCUPANCY

Since the characteristics of traffic of bicycles and pedestrians differ from those of vehicle traffic, it is not easy to directly apply the conflict indices of vehicle traffic to bicycle traffic or mixed traffic of bicycles and pedestrians.

A space occupancy index has been proposed based on the personal spaces for bicycles and pedestrians (Tsukaguchi et al., 1987). Personal space is an index that expresses the spatial sizes necessary to maintain safety on the road for bicycles, pedestrians, and vehicles. The personal space index is used to review the appropriate space distribution on roads in residential areas. This index can be applied to the analysis of the conflict phenomenon. The conflict phenomenon is defined as a condition in which other bicycles or pedestrians enters the personal space of a bicycle.

Based on the safety headway assuming the average speed of the bicycle to be 12 km/h and the length and width of the passage as 7.5 m and 1.7 m, respectively, the area of the personal space for a bicycle is 12.8 m², as shown in Figure 1. Similarly, the area of personal space for a pedestrian is 5.0 square meters.

![Figure 1 Area of personal space for a bicycle](image)

If another bicycle or a pedestrian enters the personal space of a bicycle, the bicycle might perform avoidance behaviors, such as steering, deceleration, stopping and so on, to avoid a dangerous and uncomfortable condition and to maintain the personal space. This is
considered to be a conflict phenomenon, which can express the conflict phenomenon quantitatively by measuring the number personal space incursions.

3. SURVEY OF THE TRAFFIC CONFLICT PHENOMENON

Video survey was performed on the road in Kusatsu City, Shiga, Japan. The survey spot is located on the main route between Minami-Kusatsu Station and Biwako-Kusatsu Campus of Ritsumeikan University. Heavy bicycle traffic has occurred during the periods before and after classes at the university. At the survey spot, a bicycle path has been constructed, and bicycle traffic and pedestrian traffic have recently been separated. The construction of the bicycle path was performed from September 2004 to March 2005.

In the present study, video surveys were performed before (January, 2004) and after (October, 2005) the construction of the bicycle path, in order to clarify the relationship between the conflict phenomenon and traffic conditions. Road conditions near the survey spot before and after construction are shown in Figures 2 and 3, respectively.

Before construction of the bicycle path (January, 2004), the width of the walkway was approximately 3.5 m, and bicycle use on the walkway was permitted. Most bicycles were
used on the walkway rather than the roadway. A bus stop and the entrance of a large factory were present near the survey area and many commuting pedestrians walked between the bus stop and the entrance of factory upon the arrival of a bus. Therefore, many conflicts between bicycles and pedestrians occurred on the walkway. The width of the constructed bicycle path was also approximately 3.5 m (October, 2005). Sign boards indicating the bicycle path and the walkway were installed. Therefore, bicycle traffic and pedestrians were separated almost completely.

The pre-construction survey was performed on January 6th and January 7th, 2004. Bicycle traffic on the walkway was investigated using a digital video camera from the top of a pedestrian overpass near the survey spot. The survey period is between 8:30 and 9:00, which corresponds with the peak period during which several students enter the university from the station. The survey after construction was performed on October 3rd and October 6th, 2005. Bicycle traffic on the bicycle path was also investigated using a digital video camera from the top of a pedestrian overpass near the survey spot. The survey period was between 8:30 and 9:00, which corresponds with the peak period during which several students enter the university from the station, and between 17:10 and 17:40.

The survey periods are set just before the beginning of classes (9:00) and just after the classes ended (17:20). Therefore, most all bicycles move in the direction from the station to the university during the morning and move in the direction from the university to the station during the evening. The path has a slight acclivity in the direction from the station to the university. Therefore, the average speed of bicycles during the evening was larger than that during the morning.

### 4. TRAFFIC CONFLICT ANALYSES BEFORE CONSTRUCTION

In this chapter, the traffic conflict phenomenon on the walkway before the construction of a bicycle path is analyzed. The traffic condition is mixed traffic of bicycles and pedestrians. Data collection is performed over two days: January 6th and January 7th, 2004.

The number of traffic conflicts and traffic volumes on survey dates are shown in Table 1. It is known that a greater number of traffic conflicts occurred in January 7th because the bicycle traffic volume was large.

| Table 1 Number of traffic conflicts and traffic volumes on survey dates |
|-----------------------------|---------------------|---------------------|
| Number of traffic conflicts | January 6th | January 7th |
| Number of relating bicycles for traffic conflicts | 77 | 130 |
| Bicycle traffic volume | 245 | 342 |
| Pedestrian traffic volume | 55 | 45 |

In order to clarify the relationship between traffic conditions and conflicts, the objective time period is divided into five-second intervals. The relationship between the traffic concentration on the walkway and the number of conflicts is analyzed.

Since the area of personal space of the bicycle and that of the pedestrian are different (bicycle: 12.8 square meters, pedestrian: 5.0 square meters), the area of the personal space of the pedestrian is converted to the area of personal space of the bicycle (conversion ratio: 0.39 =
The adjusted area of personal space of the bicycle is called the bicycle converted space occupancy.

The relationship between bicycle converted space occupancy and the number of conflicts every 5 seconds is shown in Figure 4. A great number of traffic conflicts occur if the space occupancy is large. Positive correlation is admitted between space occupancy and the number of conflicts. In order to decrease the number of conflicts, it is necessary to decrease the traffic concentration of bicycles.

![Figure 4 Relationship between space occupancy and number of conflicts (before construction of the bicycle path)](image)

\[ y = 430.96x^2 - 3.1353x \]
\[ R^2 = 0.8411 \]

5. TRAFFIC CONFLICT ANALYSES AFTER CONSTRUCTION

In the present chapter, the traffic conflict phenomenon on the bicycle path after construction of the bicycle path is analyzed. The traffic condition is bicycle traffic only. Traffic conditions before and after construction of the bicycle path are compared, and traffic conditions during the morning and evening periods are compared. Data collection is performed within two days: October 3rd and October 6th, 2005.

The relationship between bicycle converted space occupancy and number of conflict phenomena every 5 seconds during the morning period and that during the evening period are shown in Figures 5 and 6, respectively.

Comparing the traffic conditions during the morning before and after construction of the bicycle path, as shown in Figures 4 and 5, the difference is not large, but these traffic conflicts are decreased slightly after the construction of the bicycle path. This difference is thought to be caused by the separation of bicycle and pedestrian traffic through the construction of the bicycle path. It is considered to be possible to decrease traffic conflicts by the separation of bicycle traffic and pedestrian traffic.

Since the bicycles run downhill during evening, the average speed is greater than that during the morning. This is the reason for the difference in the traffic conditions during the morning and those during the evening. The average speed of bicycles during the morning
was approximately 15 km/h and that during the evening was approximately 25 km/h. There is a 10 km/h difference in the average speeds of bicycles during the morning and during the evening. However, the area of personal space for a bicycle is assumed to be same for both periods in the analysis.

Comparing the traffic conditions during the morning and evening after construction of the bicycle path, which are shown in Figures 5 and 6, traffic conflicts increased during the evening. This difference is caused by the difference in the average speed of bicycles. The average speed of bicycles influences the frequency of traffic conflicts. The data points fit the regression curve better during the morning period compared with that during the evening period. It might be caused by the difference in the traffic volume of bicycles. The variance of the bicycle speeds is smaller during the morning period compared with that during the evening period because the bicycle traffic volume is large.
Using the same procedure, the relationships between space occupancy and the number of conflicts in several types of traffic conditions are analyzed. The estimation results of the regression models are as follows:

1. Bicycle traffic in one direction only (morning period):
   \[ y = 393.52 x^2 - 1.8931 x \]  
   \( R^2 = 0.9114, N = 350 \)  

2. Bicycle traffic in one direction only (evening period):
   \[ y = 752.99 x^2 - 9.2896 x \]  
   \( R^2 = 0.6061, N = 361 \)

3. Mixed traffic of bicycles in one direction and walking pedestrians:
   \[ y = 126.69 x^2 + 42.535 x \]  
   \( R^2 = 0.8810, N = 41 \)

4. Mixed traffic of bicycles in one direction and bus-waiting pedestrians:
   \[ y = 239.40 x^2 + 1.1122 x \]  
   \( R^2 = 0.7823, N = 157 \)

5. Bicycle traffic in two directions:
   \[ y = 1184.0 x^2 - 27.851 x \]  
   \( R^2 = 0.8110, N = 56 \)

Where \( x \) represents bicycle converted space occupancy (veh/m²) and \( y \) represents the number of conflicts during a period of five seconds in each equation. \( R^2 \) represents the correlation coefficient of each regression model. \( N \) represents the sample number of each regression model.

The characteristics of the relationships between space occupancy and the number of conflicts are influenced by traffic conditions such as the average speed of bicycles, the direction of bicycle traffic, and mixture bicycles and pedestrians. However, the sample number is not sufficient for each condition in order to determine the differences in the relationships with traffic conditions in this survey. It is necessary to collect more sample data and to analyze the characteristics thereof in order to find the general conclusions.

6. CONCLUDING REMARKS

In the present study, a traffic conflict index using space occupancy is proposed and applied to mixed traffic of bicycles and pedestrians. As a result, the characteristics of traffic conflicts are influenced by road conditions and traffic conditions such as the average speed of bicycles, the direction of bicycle traffic, and mixture of bicycles and pedestrians.

Comparison of the number of conflicts under various road conditions and traffic conditions indicates that it may become possible to evaluate the dangers of bicycle traffic based on road conditions and traffic conditions. Comparing the traffic conditions before and after construction of the bicycle path, the difference is not large, but traffic conflicts are decreased slightly after the construction of the bicycle path. This difference is thought to be caused by the separation of bicycle and pedestrian traffic through the construction of the bicycle path.
It is considered to be possible to decrease traffic conflicts by the separation of bicycle traffic and pedestrian traffic.

For practical application, it is necessary to analyze the difference in the conflict phenomenon under various road conditions and traffic conditions and to express the relationship among the number of conflicts, road conditions, and traffic conditions. In addition, in the future reasonable road space for bicycle traffic and the separation of bicycle traffic and pedestrian traffic must be considered in order to decrease the number of conflicts.

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