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A STUDY ON IMPROVEMENT OF BUS-BAY DESIGN

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Abstracts: Bus bays have been introduced in a lot of bus stops in Japan especially where stopping buses without bays would block traffic stream seriously. In that sense, bus-bays in Japan have been evaluated as successful cases. However, based on some observations, buses in bus-bays do not stop closely at curbs, which make boarding and alighting passengers inconvenient due to big gap between buses and curbs. There might be several reasons why buses do not stop closely at curbs, including driving technical issues by bus drivers, some psychological issues for them and traffic conditions at streets. Among them, designing of bus bay is thought to be one of the factors to improve the situation. Some advanced designing can be observed in a few bus terminals but not in bus stops on the streets presumably due to safety consideration under mixed traffic condition. The authors have made several experiments to propose a new-shaped bus-bay applicable to regular streets. The proposal was applied to the real bus stop in Tokyo, which was evaluated as successful based on the observation survey and the interview survey towards the bus drivers.

Keywords: Bus-bay, Bus boarding

1. INTRODUCTION

Bus bays have been introduced in a lot of bus stops in Japan especially where stopping buses without bays would block traffic stream seriously. In that sense, bus-bays in Japan have been evaluated as successful cases. However, based on some observations, buses in bus-bays do not stop closely at curbs, which make boarding and alighting passengers inconvenient due to big gap between buses and curbs. There might be several reasons why buses do not stop closely at curbs, including driving technical issues by bus drivers, some psychological issues for them and traffic conditions at streets. Among them, designing of bus bay is thought to be one of the factors to improve the situation. Some advanced designing can be observed in a few bus terminals but not in bus stops on the streets presumably due to safety consideration under mixed traffic condition

Based on the background mentioned above, the authors set the objective of this study to propose an alternative bus bay designing for arterial streets. The proposed idea is expected to enable bus drivers to stop closely at curbs smoothly and to enable passengers to board and alight buses without minding gaps between buses and curbs.

After reviewing the related papers in this chapter, the authors introduce the first experiment to determine the detail shape of the bus bay as well as the result of the observation of buses at existing typical^-bus-bays and a bus terminal in Chapter 2. The following experiments in order to evaluate the proposed bus-bay from convenience and safety points of view are described in Chapter 3. Chapter 4 deals with the evaluation of a bus-bay proposed by the authors and introduced at a bus stop in Hachioji city in Tokyo. The conclusion of the research is shown in Chapter 5.

Several handbooks on road designing mention the shape of bus-bays on streets as well as at bus terminals in Japan, USA and European countries. As for the bus-bays at bus terminals, triangle-shape bays are introduced as good examples where buses can stop as closely as possible to curbs in order that passengers can get on and off buses without minding gaps seriously. However, in terms of bus-bays on streets, standard designs shown in those handbooks do not include triangle-shape ones presumably because of space lacking problems and safety issues. Regarding the first problem, there might be some solutions such as borrowing privately-owned land adjacent to road space. Second problems should be examined carefully, which is one of the main aspects in our experiments.

On the other hand, characteristics and problems in the existing bus-bays are analyzed by several authors, where several interesting findings are mentioned such as the tendencies that bus dwelling time (i.e. boarding and alighting time) influences traffic flow strongly, that gap between curbs and buses affect bus dwelling time and that fare collection system is another important factor on bus dwelling time.

One research group in Japan has proposed a triangle-shaped bus-bay mainly from the aspects of barrier free and snowing areas, reporting the needs of the further studies on detail design for application and safety issues.

Based on those reviews, the authors have made sure the importance of the proposal and application of new-designed bus-bay in the context of urban streets mainly focusing on safety aspects.

2. PROPOSAL OF A NEW BUS-BAY

2.1 OBSERVATION SURVEY

The authors observed how buses are stopping on typical-bus bays and at bus terminals. Firstly four bus stops were picked up and around 10 to 20 buses were observed. Table 1 and Figure 1 show the shape of those bus-bays and Table 2 shows the result of the observation

Table 1 : List of the Bus-bays Observed.

Sample No.	A	B	C	D	α
1	3.0 m	7.2 m	14.7 m	7.2 m	22.6 °
2	2,5	18.0	10.0	14.5	9.8
3	1,5	4.5	10.7	4.5	18.6
4	3,5	10.5	21.0	10.5	18.4

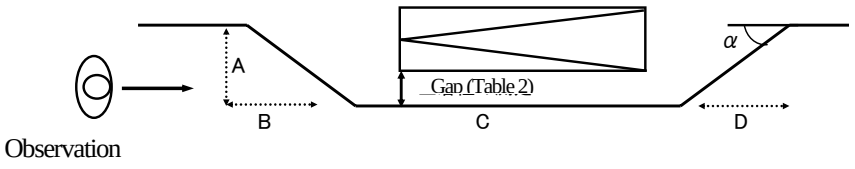


Figure 1 : Definition of Bus-bay Shape (Referring to Table 1)

Table 2 : Result of Measurement of Gaps

Sample No.	No. of buses observed	Average of Gap	Std. Deviation
1	23	0.83 m	0.45 m
2	11	0.36	0.21
3	12	0.72	0.37
4	16	0.41	0.23

From the result, difference of the shape, especially on α and D in Figure 1, was found to influence the gap. Statistical testing has shown significant difference between No.1 bus stop and No.2 bus stop, as well as No.3 bus stop and No.4 Bus stop.

Secondly, the authors made observation survey at Hiroshima Bus Center, terminal located in Hiroshima city, where triangle-shaped bus-bays are applied. Basic Dimension of bus-bays there is shown in Table 3 and Figure2. Based on the observation, more than 95 % of buses were found to have smaller gaps than 0.6 m. Average value of the gap was 0.32 m with the standard deviation 0.14 m for 28 buses.

Table 3 Basic Dimension of Bus-bays in Hiroshima Bus Center Terminal

A	B	C	D	α
8.2 m	16.3 m	8.2 m	6.9 m	6.3 °

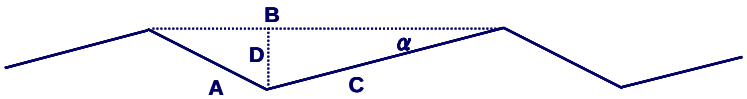


Figure 2 Definition of Bus-bays (Referring to Table 3)

Thirdly, the authors had an interview survey towards 243 bus drivers in Tokyo area asking how to feel the proposed triangle-shaped bus-bays showing its image on the questionnaire sheet. The result shows that 87 % of drivers mention the problems of existing bus-bays and that around 40 % of them feel some difficulty to use a proposed-bus-bay. Regarding the latter point, the authors classified bus drivers based on their experience as professional drivers. The authors have found that drivers with 5 or more year experiences feel less difficulty than other drivers do.

In conclusion, the authors identified the importance of a new-shape bus-bay based on triangle-shaped one which has been applied in bus terminals as well as the needs of experiments especially in order to check the feelings by bus drivers.

2.2 The first experiment to make a proposal of a new-shaped bus-bay

The first experiment was intended to get the appropriate value of C and α in Figure 2. The authors rented the field from the Bureau of Road, Yokohama City Hall and buses from a private bus operator to get those values. Regarding the portion C, 28.41m was found to be a minimum to put a bus vehicle inside the bay. As for α, several values such as 8, 10, 15 and 20 were set to check how bus vehicles move. The result shows that bus vehicles need significantly big values for A in Figure 2 in case of α takes 15 or 20. Furthermore, based on the interview survey towards bus drivers joining this experiment, they were found to feel some difficulty when buses depart from bus-bays in case of α = 15 and 20. Therefore in order to make bus-bay's space smaller, α is expected to be equal or less than 10.

3. EVALUATION OF A PROPOSED BUS-BAY FROM EXPERIMENTS

Based on the result of the previous chapter, the authors had other two experiments, renting the field and buses to evaluate the proposed bus stops especially from the viewpoints of safety.

3.1. THE FIRST EXPERIMENT

The authors proposed a triangle-shape bus-bay and checked the safety as well as the gap between a bus and the curb. In terms of the safety, the authors checked how the driver can identify the following vehicle when he departs his bus from the bus-bay. Figure 3 shows the scenery of the experiment.

Figure 3 : The scenery of the Experiment

The result of the experiment shows that even in the case of $\alpha = 8$ drivers feel difficult to identify the following vehicle at the departure. Furthermore, as shown in a Black circle on the Figure 3, the left-end part of a bus vehicle was invading the sidewalk, which might give dangerous feelings to waiting passengers and pedestrians. Therefore, the authors decided to modify the shape of the bus-bay to overcome those problems.

About the gap between buses and the curb, the authors got the average value of 0.20 m with the standard deviation of 0.05 (in case $\alpha = 8$) and 0.15 m with 0.05 (in case $\alpha = 10$), which are acceptable as significantly improved values compared with those shown in Table 2.

3.2. THE SECOND EXPERIMENT

In order to overcome the problems raised in the previous experiment, the authors again proposed a new-shaped bus-bay as shown in Figure 4. In order to understand the difference, the standard bus-bay mentioned in the road design manual formally published in Japan is shown in Figure 5.

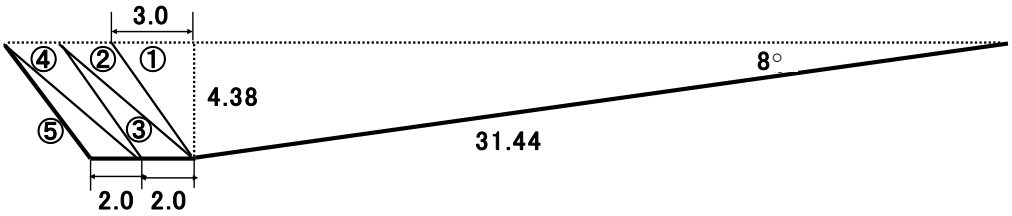


Figure 4 : A Modification of a Proposed Bus-bay with $\alpha = 8$

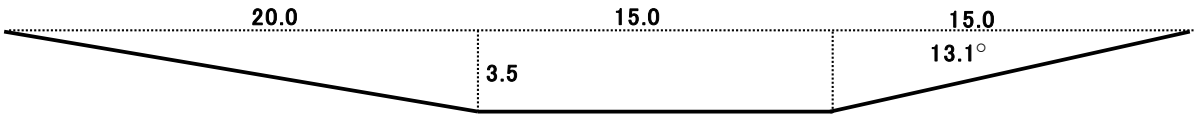


Figure 5 : An existing Standard of a Bus-bay

As shown in Figure 4, there are several alternative shapes in terms of the left-side of the bay. The authors executed ten patterns in total (5 patterns in case of $\alpha = 8$ as shown in the figure and other 5 patterns in case of $\alpha = 10$) to check how the problems mentioned in the previous section are overcome. Figure 6 shows the scenery of the experiment.

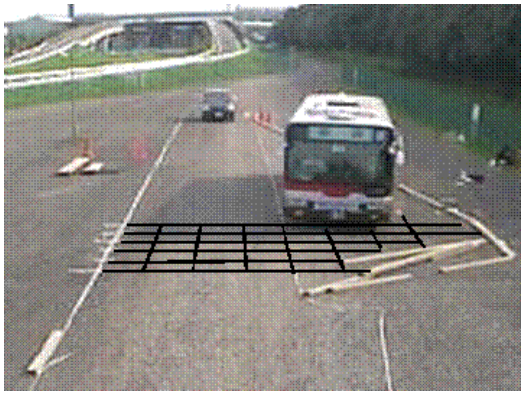


Figure 6 : The Scenery of the Second Experiment

In terms of the problems of the invasion of a bus body inside the sidewalk was clearly overcome for only a few cases of alternative designs (only ③, ④ and ⑤ in Figure 4). Therefore, a triangle shape cannot be recommended from the safety aspect in case that the bay is installed on streets. As for the other problems, the authors checked how much portion of the following vehicle can be identified by the driver, by setting the video-camera recorder as shown in Figure 7.

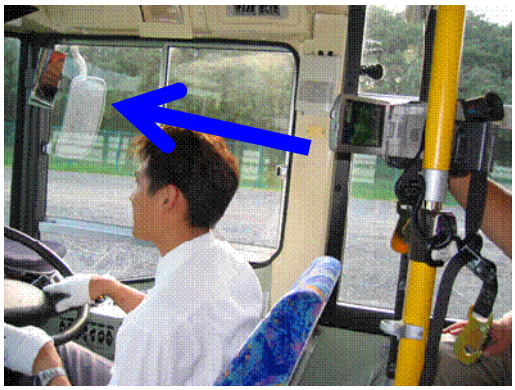
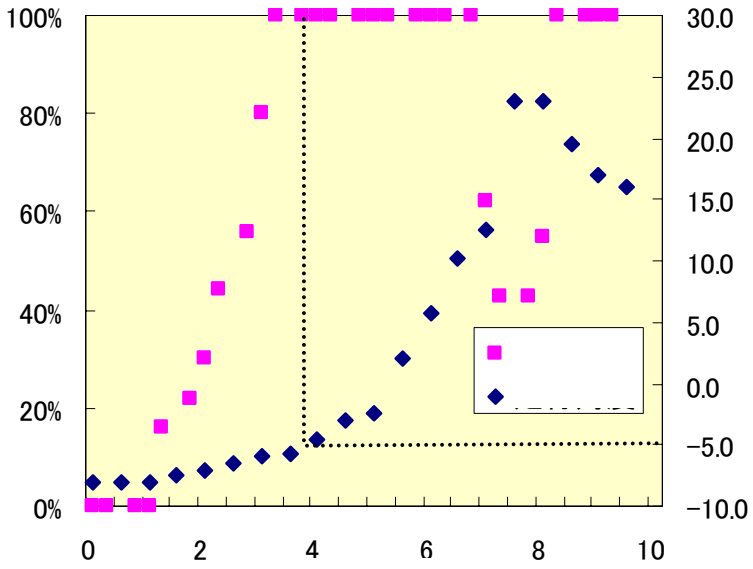


Figure 7 : The Scenery of the Video-camera Survey

Figure 8 shows the relationship between the portion of the following car and the time after the bus departs in case of ③ in Figure 4. As shown in the figure, the driver cannot identify the following car just after the departure, or precisely for 1.3 second, which is found acceptable based on the interview survey to the drivers joining the experiment under the condition that the driver checks the mirror carefully several times just after the departure.

In conclusion, the authors have finalized the proposal of a new-shape bus-bay especially from safety points of view at the departure of the bus from the bay.



Left vertical axis : portion (size %) of the following car in the mirror （■）
Right vertical axis :angle(°) of the bus body from the direction the street （◆）
Horizontal axis : time (second) passed from the departure

Figure 8 : The Portion of the Following Vehicle

4. INSTALLATION OF THE PROPOSED BUS=BAY ON THE STREET

Based on the findings shown in the previous chapters, the authors had several meetings with the Ministry of Land, Infrastructure and Transport to install the proposed bus-bay in the real field, with support from the Metropolitan Police Agency. After the consultation, the bus-bay was introduced at one bus stop in Hachioji City in Tokyo Metropolitan Region. The finalized shape of the bus bay was shown in Figure 9 as well as the photo in Figure 10.

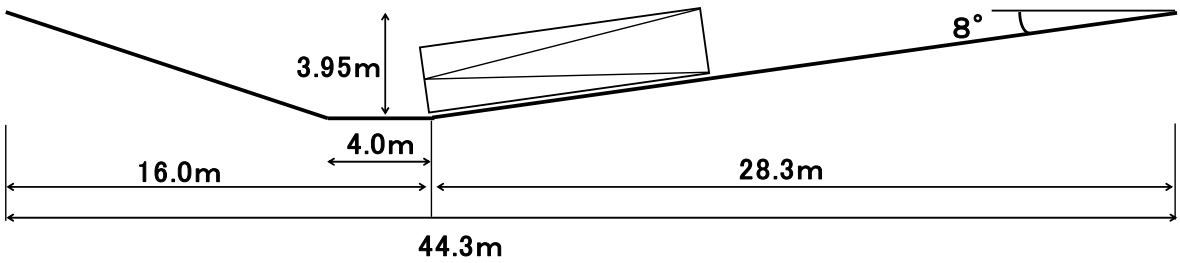
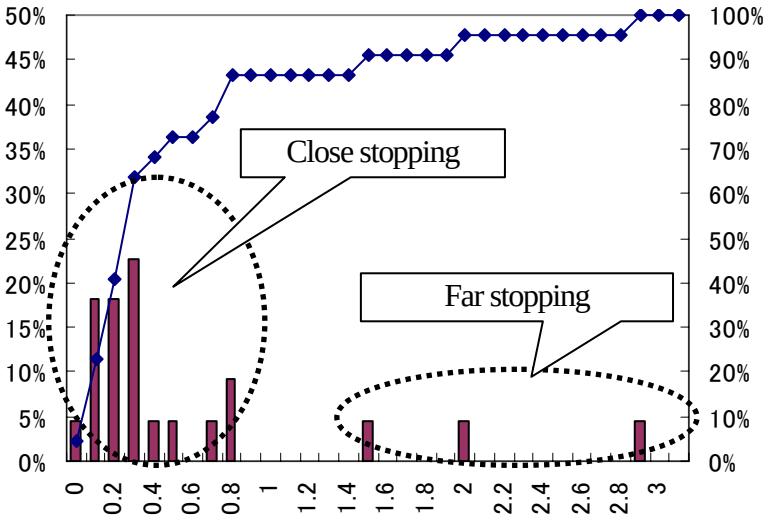


Figure 9 : The Finalized Shape of the Bus-bay Introduced in Hachioji

Figure 10 : Scenery of the Proposed Bus-bay in Hachioji

The authors had the observation survey just one month after the introduction to see the gap between buses and the curb. The result is the average value 0.51 m with the standard deviation 0.70 m for 22 buses, which seems worse than those values in Hiroshima Bus Center terminal. The authors carefully examined the gap data as shown in Figure 11.



Left vertical axis : share of buses (bar chart)
Right vertical axis : accumulated share of buses (line chart)
Horizontal axis : gap between buses and the curb

Figure 11 : Gap Data Distribution At a Bus-bay in Hachioji

As shown in the figure, 3 buses were stopping very far from the curb, whose image was described in Figure 12. If those 3 samples are excluded from the calculation, the average gap will be 0.27 m with the standard deviation of 0.22m, whose values are not significantly different from those in Hiroshima Bus Center terminal based on the statistical testing.

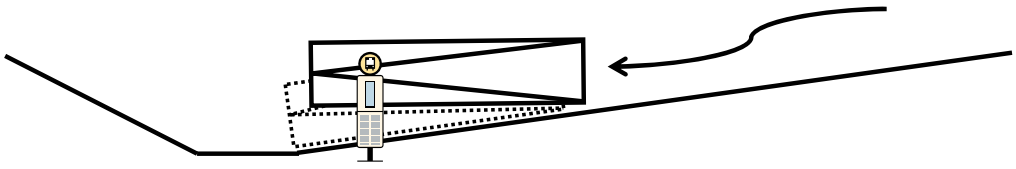


Figure 12 : Extreme Cases of Stopping

In order to know the extreme cases, the author had the interview survey towards 91 bus drivers who was using this bus stop. By applying the discriminant analysis towards the data, the following model shown in Table 4 was acquired, which implies elderly drivers with experiences of 40 years or more feel some difficulties to fit themselves used to the new shaped bus-bay, although in general many bus drivers accept the proposal mentioning the necessity of some improvements such as road marking sign designing.

Table 4: The Result of the Discriminant Analysis Based on the Interview Data toward Bus Drivers.

Significant Variables	Partial Correlation Coefficient	Range (Quantification Theory II)
General attitude for gaps	0.090	1.085
Worrying time loss at departure	0.223	1.535
Experiences of Driving	0.212	1.504
Accuracy Rate	72.53 %	

Dependent Variable: Feel less difficulty to minimize the gap at the new bus stop or not
Since the most explanatory variables are discrete, the Quantification Theory II software, which is mathematically equivalent with Discriminant analysis, was applied

5. CONCLUSION

The authors made several experiments and finalized the new shaped bus stops. The proposal was applied into the real field, where the authors had the observation and interview surveys, from which the proposal was found to be effective to reduce the gap between buses and curbs although some improvements are needed.

As the topics for the further study, space requirement, coordination with waiting facilities and arrangement with bike lanes should be considered more carefully. Furthermore, bus-bays for minibuses, which have become quite popular recently in Japan in narrower streets, where a lot of elderly residents want to improve their mobility.

ACKNOWLEDGEMENT

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