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Study on Statistical Distribution of Bus Dwell Time

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ABSTRACT

A bus service comprises three elements: operation, service at a bus stop and waiting for a signal. Service at a bus stop comprises arrival at the stop, boarding and alighting and departure from the stop. The time required for service at a stop is defined as bus dwell time. Bus dwell time accounts for 9~11% of total bus operation time, and, thus, understanding Bus dwell time accurately is very important in establishing and managing a bus operation schedule. To this end, the distribution of the dwell time of a bus route in downtown Seoul, which has most complicated public transportation network in Korea, was identified in this study. Consequently, Bus dwell time shows a right-skewed distribution, which will be used as the base for effective bus operation.

Keywords: *Bus service, dwell time, BMS, BIS, distribution*

1. INTRODUCTION

A bus service comprises three elements: operation, service at a bus stop and waiting for a signal. Service at a bus stop comprises arrival at the stop, boarding and alighting and departure from the stop, as in Fig 1. The time required from arrival at a stop to departure us called Bus dwell time. Bus dwell time is one of the three elements comprising bus services and is also a critical factor determining service quality. That is, Bus dwell time may either increase or decrease the passenger's satisfaction.

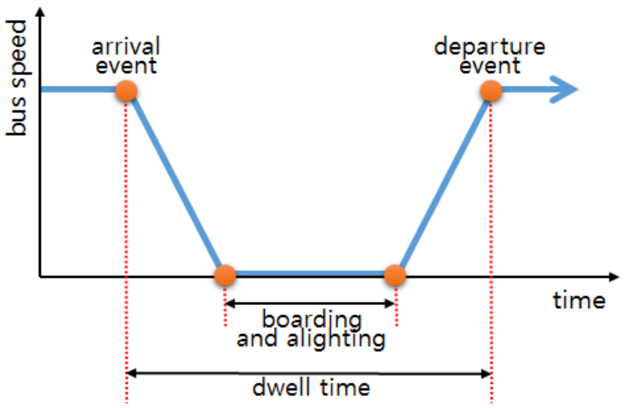

Figure 1: Dwell time at a bus stop

Bus service management has so far focused on travel time between stops. That is, management has been limited to road operation only among bus service elements. As suggested in the study by Maloney and Boyle (1999)[1], Bus dwell time accounts for 9~11% of total service time.

Despite the importance in determining service quality, study on this element has been relatively lacking, compared to study of other elements. In this study, the data on the dwell time of the buses running in downtown Seoul was collected and analyzed. In Korea, real-time management of the bus service is in process. Bus Management System (BMS) and Bus Information System (BIS) dwell time was estimated using the arrival and departure time collected by BMS. Dwell time estimated together with Fu's study (2003)[2] would be helpful in planning and designing the bus routes.

2. RELATED STUDIES

Bustransit service reliability is closely dependent on bus operation speed, dwell time at a stop, the driver's layover time and the length of the bus route. Li and Li (2006)[3] suggested dwell time as the critical factor in determining bus transit service quality. According to Maloney and Boyle (1999)[1], dwell time accounts for 9~11% of bus travel time.

Preceding studies on dwell time have focused on increase as depending on the number of passengers. Levinson (1983)[4] proposed five seconds of mean time and an increase of 2.75 seconds per passenger. Guenthner and Sinha (1983)[5] asserted a relationship between dwell time and the fare collection system.

The studies on dwell time have been limited to the importance of dwell time and its effect on a bus operation service, and studies were conducted to prove the relationship between dwell time and the number of passengers. In fact, a study on the statistical distribution of dwell time has yet to be conducted, and dwell time in establishing a bus operation schedule has been limited to applying the mean value from similar routes.

3. DATA

Seoul city introduced BIS and BMS in 2006, and, since then, information has maintained a 95% level of accuracy. As in Fig 1, a total of 11 bus stops in downtown Seoul were included in the review. Bus stops were on between five and 13 routes.

Data were collected on May 19, 2009 (Tue) using BMS and BMS data provided by the Seoul Transport Operation and Information Service Center (TOPIS)

Out of 11 stops, ⑨, ⑩ and ⑪, where buses stop more frequently, were selected as priority analysis stops, and Nos ⑤, ⑦ and ⑧, where the same buses stopping at ⑨, ⑩ and ⑪ stop, were additionally included.

Thus, dwell time analysis was conducted with six stops. Data collection was made from 07:00 till 19:00 for 12 hours, and dwell time analysis considering operational characteristics was conducted by time zone, morning peak (07:00~09:00), non-peak (12:00~14:00) and afternoon peak (17:00~19:00). A total of 15 routes use these bus stops as in Table 2. The operational characteristics of the buses using these stops are as in Table 2. Buses are in operation with a headway of four to five minutes.

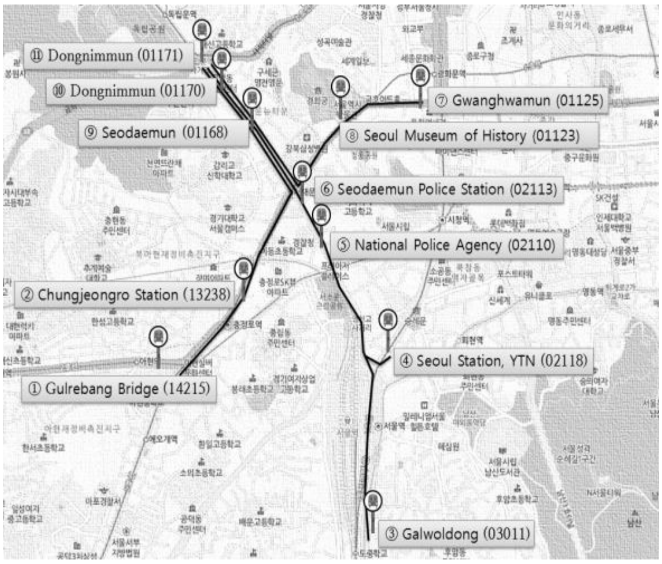

Figure 2: Bus stop data collection: CBD in Seoul, Korea

Table 1: Bus stop validation and the results of route selection

Class.	Bus Stop / ID	# of Bus
⑤	National Police Station (02110)	701, 702, 703, 750, 752
⑦	Gwanghwamun (01125)	370, 470, 471, 601, 720, 704
⑧	Seoul Museum of History (01123)	370, 470, 471, 601, 704, 710, 720
⑨	Seodaemun (01168)	171, 370, 470, 471, 601, 701, 702, 703, 704, 710, 720, 750, 752
⑩	Dongnimmun (01170)	370, 470, 601, 703, 710, 750
⑪	Dongnimmun (01171)	171, 471, 701, 702, 704, 720, 752

Where, minimum headway is based on peak time while maximum headway is based on non-peak time. Difference in headway between peak time and non-peak time was 2 minutes to 10 minutes in maximum. The longer the headway the larger the difference between maximum headway and minimum headway, like bus No. 704 and 752. Such interval is dependent on ridership. Extended interval was attributable to less ridership.

Table 4 shows the statistical analysis results of dwell time by bus stop. A mean dwell time was 37.7sec to 47.4 sec and the deviation was not significant. On the contrary, dwell time by stop was 5 sec to 73sec, more than 15 times in difference, which was attributable to a large difference in dwell time between peak time and non-peak time. Thus analysis of dwell time separately by peak time and non-peak time would be rational.

Table 4 shows the result of dwell time analysis by bus route. Dwell time by route was 37.2 to 73.0 sec and standard deviation distribution was 59.1 at 8.4.

As a result of analyzing dwell time by bus and by stop, mean value was around 1 minute showing low variation but high deviation. Thus deviation would be increased when applying the mean value equally to bus operation schedule. This study is intended to review the statistical distribution characteristics of dwell time and propose the optimal dwell time based on review. To that end, dwell time was plotted by classifying it into morning peak, afternoon peak and non-peak times, and the outcome was used to identify the characteristics of dwell time distribution.

Should dwell time follow normal distribution, using a mean value would be appropriate, but, when skewed, using a mode or median value would be rational.

Table 2: Headway of buses

	Headway (weekdays)		
	Max. (a)	Min. (b)	(a)–(b)
171	6	10	4
370	4	7	3
470	6	11	5
471	4	6	2
601	6	10	4
701	8	10	2
702	4	10	6
703	6	10	4
704	10	20	10
710	6	13	7
720	7	10	3
750	4	12	8
752	4	14	10

4. ANALYSIS

Dwell time was calculated as below:

$$t^i = t^i_{depart} - t^i_{arrive}$$

where t^i : dwell time for a bus

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t^{i}_{depart}: time of a bus departing from a stop

t^{i}_{arriv} : time of a bus arriving at a stop

$(t^{i}_{depart} > t^{i}_{arriv})$

Table 3 shows the statistical analysis result of dwell time by bus stop. The mean dwell time was 37.7 sec to 47.4 sec, and the deviation was not significant.

Table 3: Dwell time distribution at bus stop

Class.	⑤	⑦	⑧	⑨	⑩	⑪	total
# of Data	938	1,048	1,346	1,438	712.0	874	6,356
Max.	179	158	144	175	264	161	264
Min.	8	7	6	5	6	8	5
Ave.	41.8	39.8	47.4	45.9	37.7	43.8	43.4
St. Dev.	21.4	13.4	18.6	17.6	21.4	24.3	19.6
Var.	456.5	178.9	344.2	310.5	457.5	589.3	383.0

As a result of analyzing dwell time by bus and by stop, the mean value was around one minute, showing low variation but high deviation. Thus, deviation would be increased when applying the mean value equally to the bus operation schedule.

This study is intended to review the statistical distribution characteristics of dwell time and propose an optimal dwell time based on review.

To this end, dwell time was plotted by classifying it into morning peak, afternoon peak and non-peak times, and the outcome was used to identify the characteristics of dwell time distribution.

Should dwell time follow normal distribution, using a mean value would be appropriate, but, when skewed, using a mode or median value would be rational.

5. DISTRIBUTION OF DWELL TIME

Dwell time distribution in the morning peak, afternoon peak and non-peak times is as in Figs 3, 4 and 5. In all cases, the mean value was greater than the median value as right-skewed (positive skewness), which implies a problem when applying the mean value as equally as dwell time.

Table 4: The mean and standard deviation of dwell time

Class.	Bus Stop / ID	Dwell Time (Ave., St. Dev.)												
		171	370	470	471	601	701	702	703	704	710	720	750	752
⑤	National Police Station (02110)	-	-	-	-	-	64.3, 27.7	47.1, 26.6	58.3, 38.4	-	-	-		
⑦	Gwanghwamun (01125)	-	40.8, 10.1	42.7, 11.9	-	-	-	-	-	45.6, 22.6	41.7, 12.3	39.5, 15.1	-	-
⑧	Seoul Museum of History (01123)	-	53.4, 22.6	44.5, 14.9	-	52.5, 20.7	-	-	-	62.5, 22.0	48.3, 25.1	48.0, 17.1	-	-
⑨	Seodaemun (01168)	63.7, 26.9	64.0, 27.9	57.4, 26.2	63.2, 15.3	61.5, 28.0	64.1, 10.8	72.8, 24.2	67.5, 25.0	73.0, 20.0	55.4, 25.1	66.4, 33.6	66.7, 16.2	67.9, 25.2
⑩	Dongnimmun (01170)	-	51.2, 19.4	51.0, 28.5	-	68.7, 59.1	-	-	-	-	51.1, 35.3	-	47.9, 20.4	-
⑪	Dongnimmun (01171)	52.2, 36.5	-	-	44.9, 20.4	-	45.1, 26.8	37.2, 8.4	-	44.5, 20.6	-	51.3, 23.0	-	68.6, 35.4

Table 4 shows the result of dwell time analysis by bus route. Dwell time by route was 37.2 to 73.0 sec, and the standard deviation distribution was 59.1 at 8.4.

On the contrary, dwell time by stop was 5 sec to 73 sec, more than a difference of 15 times, which was attributable to a large difference in dwell time between the peak time and the non-peak time. Thus, analysis of dwell time separately by the peak time and the non-peak time would be rational.

A right-skewed distribution means a case in the form of a long tail at the right side. In such a case, an excessively large value may be applied when using a mean value. Particularly in the afternoon peak, a right-skewed distribution with a concentration of passengers appeared.

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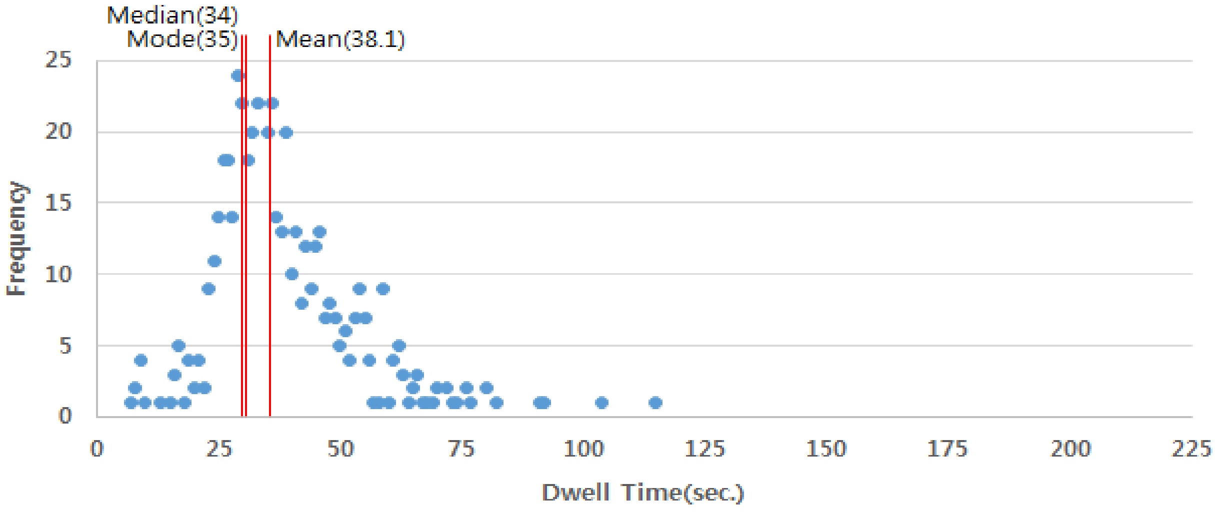

Figure 3: Morning peak

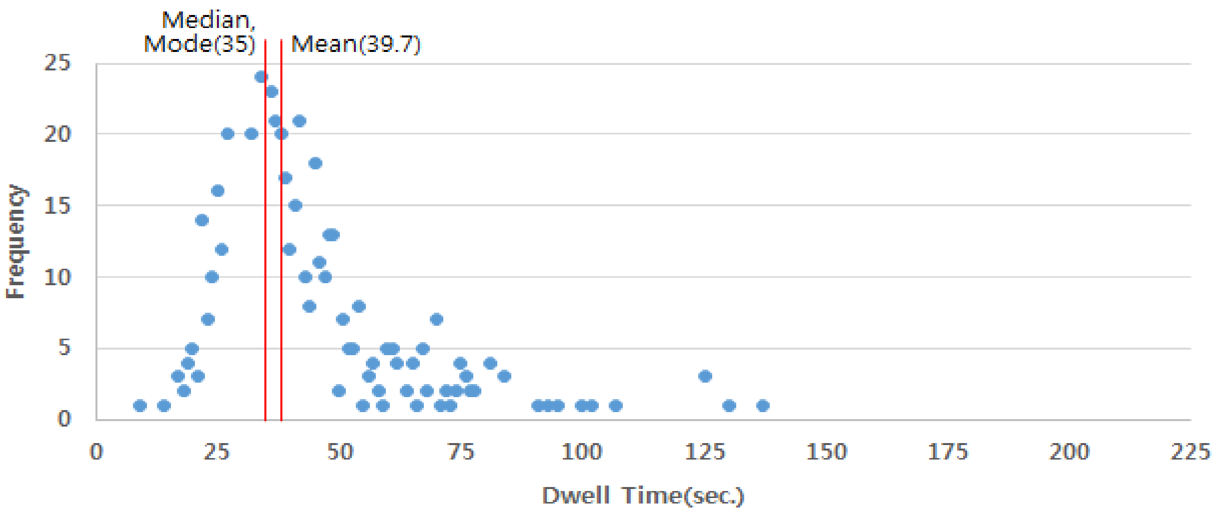

Figure 4: Non-peak

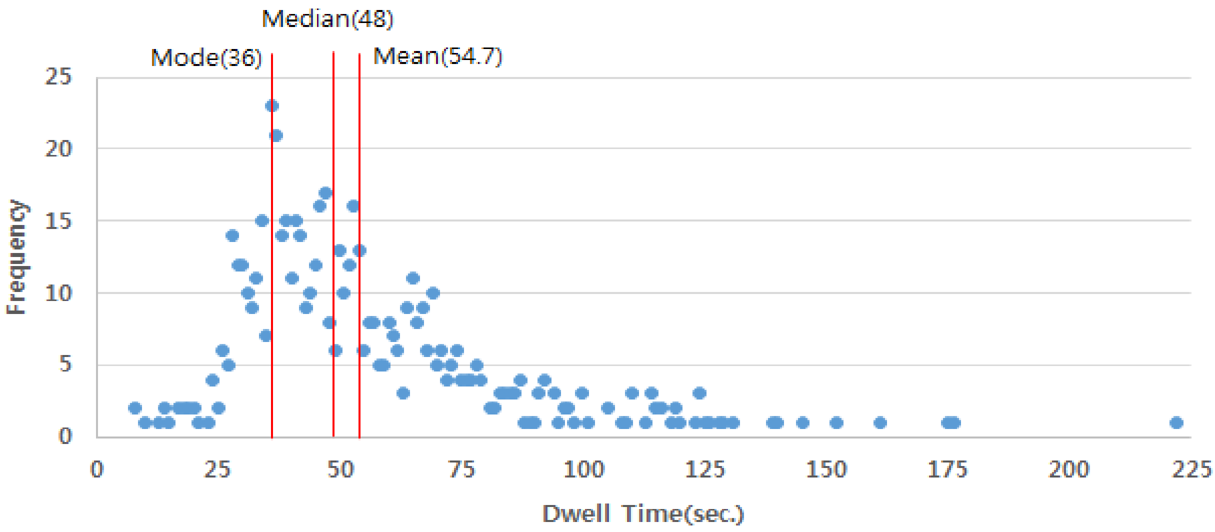

Figure 5: Afternoon peak

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6. CONCLUSION

In this study, the distribution of dwell time at a stop was identified by plotting. A mean value was adopted for dwell time used for the bus operation schedule because the dwell time distribution was assumed to follow a normal distribution. As a result of plotting the dwell time distribution of the buses in the operation, a skewed distribution, instead of a normal distribution, was found. Such a pattern appeared in the afternoon peak. The cause and result of the characteristics of the afternoon peak are as follows. In general, the passengers are concentrated in a certain time zone, and the headway of a bus is shortened, which promotes quick service at stops. Thus, the mode appears as a small value. On the contrary, a bus often provides a boarding and alighting service at stops over an extended time because of the concentration of passengers. Thus, when establishing the operation schedule by applying the mean value of dwell time at stop, the deviation would possibly be significant.

According to the outcome from this study, the mode or median value would be more rational for dwell time at a stop in the case of stops with such characteristics. The modes at morning peak, afternoon peak and non-peak times were all similar to each other, indicating 34~35 seconds. When applying the same value irrespective of the time, using the mode would be more appropriate.

As a result of reviewing the plot result, dwell time follows a gamma distribution instead of a normal distribution. Hence, a dwell time estimation model using gamma distribution is proposed for further study.

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