Evaluation of Punctuality in Fixed Route Bus by Using Simulation

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1. INTRODUCTION

In many developing cities, buses have been served as major public transportation system. An operation of bus has uncertainty on punctuality of arrival time at bus situations. It was caused by the reasons inappropriate on the route setting, traffic jams occurring in various places and operation entrusted by each bus drivers. On the other hand, in some cities, the tracking service for bus by installing GPS has been launched. Those cities try to optimize for bus operation from GPS data. The object of this study is to analyze the punctuality by simulation under the any traffic situation and examine what kind of factors is influenced on punctuality.

2. LITERATURE REVIEW

Seung et al. proposed three punctuality indicators using the validation of difference regarding on arrival time between two bus. There were some studies to analyze punctuality of route bus in Seoul by using indicator. From these result, first bus stop punctuality keep 80% for between first arrived bus and second bus, however punctuality was deteriorated as approaching to end final bus stop.

Takagishi et al. showed difference service time when headway for before and after buses was changed in operation.

3. METHOD OF RESURCH

3.1 Definition of punctuality indicator

The punctuality of bus is shown by Eq. (1) and (2) which proposed by Seung et al. P of Eq. (1) is the ratio of the square of the average gap of operation headways and the square of the variance ratio. This square of the variation calculates square of difference real operation headway for bus and scheduled operation headway of bus. The lager of Eq. (1), the higher Punctuality.

$$P = \frac{s^2}{h^2} \tag{1}$$

$$s^2 = \frac{1}{I-1}\sum_{i=2}^{I}\left(h_i - h_t\right)^2 \tag{2}$$

Here, P : Punctuality Index（Regard percentage of P as punctuality.）, h : Operation headway on schedule [s], s : Variance of the difference between the actual operation headway and the scheduled operation headway, I : Number of bus operations, h_i : The i-th operation headway [s]

As the value of P increases, the difference between the actual operation headway and the schedule operation headway increases, indicating that the operation headway is varies greatly.

3.2 Definition of waiting time

Waiting time of passenger at each bus stops is shown by Eq.(3).

$$\overline{X} = \frac{\sum X_{ij}}{N} \tag{3}$$

Here, $\overline{X}$: Waiting time in each bus stops, N_{ij}: Number of buses, X_{ij}: Arrival time interval at the bus stop with the previous bus

3.3 Method of simulation

Bus simulation was carried out, which used the virtual bus route, and whether punctuality indicator selected in preceding section possible of estimate. In addition, Simulation carried out change factors.

(1)Route of Bus

The virtual bus route was show in figure 1.

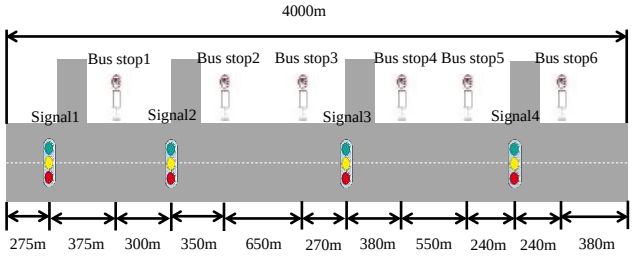

Figure1 Route of Bus on the simulation

(2) Terms of simulation

Simulation was carried out under the fixed factors shown table 1, and the variation factors is shown at table 2. Simulation pattern was configured at table 3.12 which combinations in order to consider difference all variation factors combinations. 25 buses data was collected from bus simulation, however first 5 data wasn't considered for estimating index because traffic situation was incompletely produced in simulation.

Table 1 Fixed factor

Terms of simulation (Fixed factor)
Never to stop except for bus stops and intersections.
Bus stops and intersections are sure to stop.
Keep traffic conditions constant for Road width etc.
Regard service time per one person as 2 sec.
Assume an advance payment system, and regard a period of time spent boarding is longer as than get off time.

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Table 2 Variation factors

Terms of simulation (changing the variation factors)	Terms	content
Stop time at intersection	A_1	Keep stop time constant for all intersections.
	A_2	Using random stop time (for 1 sec ~30 sec) for each intersections.
Number of passengers	B_1	Keep number of passenger constant for all bus stops.
	B_2	Change the number of passengers according to the normal distribution using the average number of passengers at each bus stop.
velocity and accelerated velocity	C_1	Set all bus velocity to average speed.
	C_2	Change the speed of each bus according to the normal distribution using non-peak speed. (accelerated velocity: a=0.5 m/s^2)
	C_3	Change the speed of each bus according to the normal distribution using peak speed. (accelerated velocity: a=0.35 m/s^2)

Table 3 Combination of simulation

	Combinations		Combinations		Combinations		Combinations
Ⅰ	$A_1B_1C_1$	Ⅳ	$A_1B_2C_1$	Ⅶ	$A_2B_1C_1$	Ⅹ	$A_2B_2C_1$
Ⅱ	$A_1B_1C_2$	Ⅴ	$A_1B_2C_2$	Ⅷ	$A_2B_1C_2$	Ⅺ	$A_2B_2C_2$
Ⅲ	$A_1B_1C_3$	Ⅵ	$A_1B_2C_3$	Ⅸ	$A_2B_1C_3$	Ⅻ	$A_2B_2C_3$

4. RESULT OF ANALYSIS AND EXAMINATION

Punctuality for each bus stop is shown in figure2.

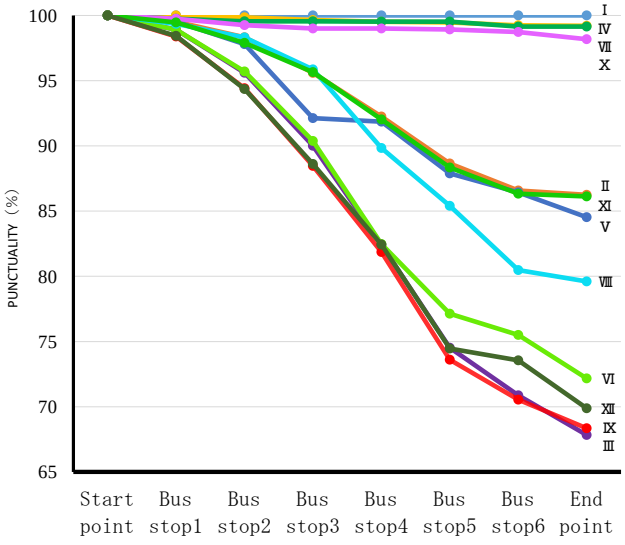

Figure 2 Punctuality for each combination

The figure 2,It was clarified that punctuality are split three groups (Ⅰ,Ⅳ,Ⅶ,Ⅹ),(Ⅱ,Ⅴ,Ⅷ,Ⅺ),(Ⅲ,Ⅵ,Ⅸ,Ⅻ). This three groups are sprit by bus operation speed of pattern C_1, C_2 and C_3. C_1, C_2 and C_3 standard deviation are 0km/h (C_1), 12.96km/h (C_2) and 15.48km/h (C3).Punctuality deteriorate from C_1 (Ⅰ,Ⅳ,Ⅶ,Ⅹ), C_2 (Ⅱ,Ⅴ,Ⅷ,Ⅺ) and C_3 (Ⅲ,Ⅵ,Ⅸ,Ⅻ) in order.

Next in figure 2, it is grasped that impact on punctuality is occurred by number of passenger. Bus operation speed use the C_1, and punctuality compare fixed number of passenger pattern(Ⅰ , Ⅳ) and change number of passenger pattern(Ⅶ, Ⅹ). In addition, bus operation speed use the C_1 and punctuality compare fixed waiting time pattern at intersection (Ⅰ,Ⅶ) and change waiting time pattern at intersection (Ⅳ,Ⅹ).From this comparison, number of passenger at bus stop and waiting time at intersection clarified that punctuality decrease slightly by difference number of passenger at bus stop and waiting time at intersection. That is to say, difference bus speed is bigger cause for decrease of punctuality than other factor.

Next, it was confirmed whether punctuality indicator can express for punctuality. Identification method used average waiting time in each bus stop. The figure 3 and figure 4 compare the standard deviation of the average waiting time when the punctuality is 99% and 98%. The standard deviation of the average waiting time is nearly the same. So it can be said that punctuality indicator can cover any traffic situation.

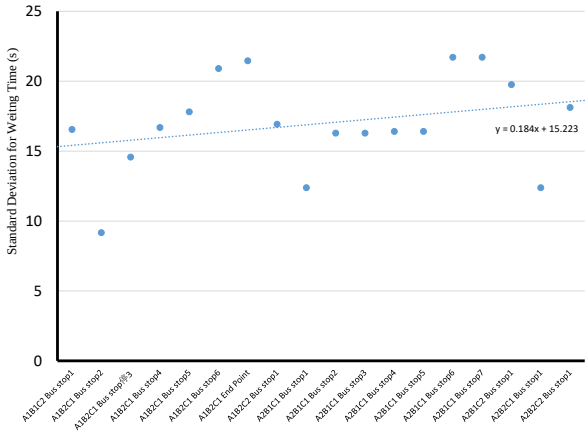

Figure 3 Standard deviation of waiting time when the punctuality is 99%

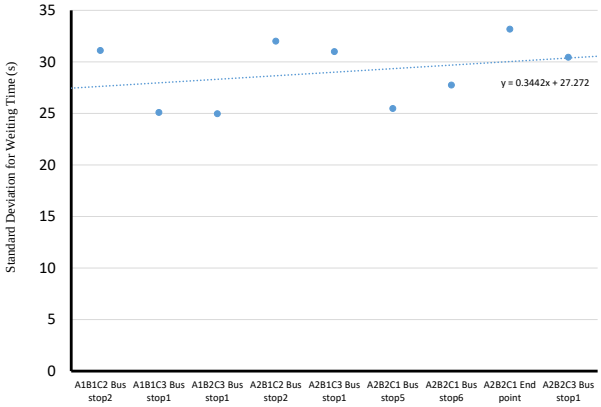

Figure 4 Standard deviation of waiting time when the punctuality is 98%

5. CONCLUSION

In this study, simulation using three variation factors was carried out. In addition, punctuality indicator was examined whether it has possibility to use evaluation for bus operation. As a result, punctuality indicator possible that it could estimate for any traffic situations. So it can be Saied, Punctuality indicator can use when assess for bus operation.

Forthcoming challenges should be to confirm whether reliability of the punctuality index by using simulation for like real bus operation. For example consider the effects of other traffics on buses, change service time for per parson and signal control.

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