ANALYSIS ON INFLUENCE OF GEOMETRIC DESIGN ON GAP PARAMETERS AT ROUNDABOUTS

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1. Introduction

Roundabout was first defined and prescribed to Road Traffic Law of Japan in June 2013, and it took effect from September 2014. For the introduction of roundabout, the analysis of entry traffic capacity is indispensable. In Roundabout Manual[1] in Japan, which was published in 2016, entry capacity can be estimated by equation (1).

$$c_i = \frac{3600}{t_f}(1-\tau \cdot Q_{ci}) \cdot \exp\{-\frac{Q_{ci}}{3600} \cdot \left(t_c - \frac{t_f}{2} - \tau\right)\} \quad (1)$$

Where, c_i: entry capacity of entry i[veh/h], Q_{ci}: circulating flow for i[veh/h], t_c: critical gap[sec], t_f: follow-up time of entry vehicle[sec], τ: minimum headway of circulating flow[sec]. Here, t_c, t_f, τ are called as "gap parameters" and recognized as the most important variable which reflect driver's gap acceptance behavior. However, the impact of geometry is not considered in equation (1), although it would be significant on driver's behavior.

Kimber[2] introduced a regression model for entry capacity using geometric parameters of roundabout, based on the data of 86 places in the UK, as shown in equation (2). This equation is adopted in the Guideline of the UK[3].

$$c_e = k \cdot (F - f_c \cdot q_c) \quad (2)$$
$$k = 1 - 0.00347(\varphi_o - 30) - 0.978(1/r - 0.05)$$
$$F = 303x_2 (veh/h)$$
$$f_c = 0.21T_D(1 + 0.2x_2)$$
$$x_2 = v + (e - v)/(1 + 2S)$$
$$T_D = 1 + 0.5/\{1 + \exp[(D - 60)/10]\}$$
$$S = (e - v)/l'$$

Where, e is entry width[m], v is approach half width[m], l is effective flare length[m], r is entry radius[m], φ_o is entry angle[deg], S is sharpness of the flare, D is inscribed circle diameter[m], as illustrated in Fig.-1.

In previous research in Japan, Kanbe, et al[4], attempted to analyze the impact of geometric parameters on gap parameters so as to include the impact of geometry in Equation (1), but uncertainties still exist. Therefore, the objective of this paper is to further analyze the influence of geometric parameters, based on the empirical data in Japan.

2. Methodology

To analyze the relationship between geometric parameters and gap parameters, empirical data was collected at three roundabouts in Japan, i.e., Towacho in Nagano Prefecture, Hitachitaga in Ibaraki Prefecture and Itoman in Okinawa Prefecture (Fig.-2). Geometric parameters are defined consistent with Kimber's model, and summarized in Table-1. Here, entry angle φ_o by Kimber is named as outflow angle, and additional parameter φ_e is newly defined as entry angle, because φ_e seems to be more reasonable to represent the angle of the entry. In addition, it should be noted that the entry control of Towacho is 'Stop', while other two roundabouts have 'Yield' control.

Gap parameters were extracted from the video recordings.

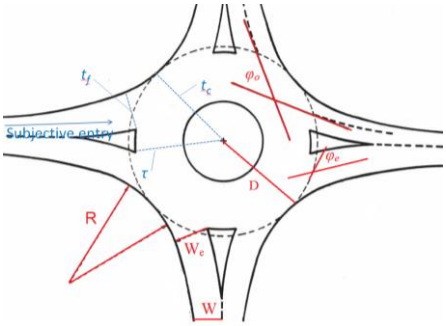
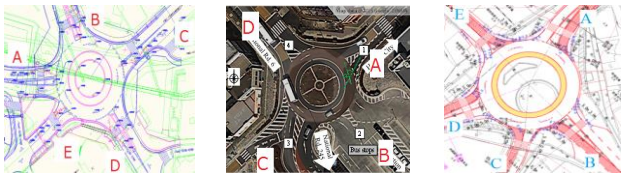


Fig.-1 Definition of geometric parameters and Cross section for measuring gap parameters

Table-1 Geometric design parameters for the analysis

Round about	Entry	W_e (m)	W (m)	D (m)	R (m)	φ_e (deg)	φ_o (deg)
Towacho	A	4.49	3.00	30	13.0	69	107
	B	4.41	2.92		13.5	66	96
	C	3.92	3.33		13.5	62	90
	D	5.00	3.43		13.5	71	69
	F	3.45	2.75		6.5	65	124
Hitachitaga	A	4.70	3.25	28	11.0	32	68
	C	4.44	3.00		5.5	56	23
	D	5.35	3.25		13.0	26	28
Itoman	A	4.15	3.00	39	21.5	43	30
	B	3.87	3.00		23.5	40	79
	C	3.26	3.00		6.0	45	74
	D	3.99	3.00		21.5	37	53
	F	3.74	3.00		39.0	33	57



Towacho RAB Hitachitaga RAB Itoman RAB

Fig.-2 Plane graph of three roundabouts

Fig.-1 also shows the cross section used for measuring each of three gap parameters. This time, only the headways of passenger cars are analyzed in order to exclude the impact of vehicle type. Critical gap t_c is determined by the intersecting point of the cumulative distribution of the accepted and rejected gap which are shorter than 10[sec] (Raff method). Follow-up time t_f and minimum headway of circulating flow τ are defined by the 15 percentile value of the headway distributions of entry and circulatory roadway which are shorter than 5[sec].

3. Analysis

The gap parameters are obtained as shown in Tables-2, 3 and 4.

For critical gap t_c, although multiple regression is conducted to analyze the relationship with geometric parameters, no parameter is found to be statistically significant.

Meanwhile, it is observed that, the t_c of left-turning and through vehicles are shorter than right-turning vehicles. Here the angle between entry lane and outflow lane of left turning is less than 170°, that of through is between 170° and 190° and that of right-turning is more than 190°. As a result, a significant trend of t_c: left turning < straight ahead < right turning is shown especially at Towacho RAB. This is because, for right-turning vehicles, drivers need be more slowly before stop line than left-turning and through. On the other hand, such trend is not clearly shown in Itoman RAB. On the other hand, such trend is not clearly shown in Itoman RAB. One reason is the small sample size of left-turning and right-turning vehicles. The other may be that the size of Itoman RAB is much bigger than Towacho RAB, so the distance between the entry lane and left-turning outflow lane is bigger, therefore the trend is not significant.

For entry follow-up time t_f, multiple regression is also conducted, and both of entry angle φ_e and outflow angle φ_o are found to be significant, as shown in Table-5. This means the follow-up time increases with the increase of entry angle and outflow angle. When the entry angle approaches right angle, it is harder for drivers to turn into circulatory roadway. However, t_f in Towacho is likely to be under estimated. That may be due to the 'Stop' control which was applied only at this roundabout among these three sites.

For minimum circulating headway, the result is shown in Table-6. It is found that the larger the inscribed circle diameter is, the shorter the minimum circulating headway τ becomes. This is because it is easier for drivers running in a bigger inscribed circle.

4. Conclusions

This paper analyzed the impact of geometric parameters on three gap parameters. Through the analysis, it is found that:

For critical gap, although geometric parameters are not significant in regression analysis, results indicated that OD of entry vehicles may influence t_c, but more data is necessary to analyze more in detail.

For entry follow-up time, it is influenced by entry angle and outflow angle, due to larger angle makes vehicles hard to turn in and need to slow down when enter the circulatory roadway.

For minimum circulating headway, it is influenced by inscribed circle diameter; due to larger inscribed circle is easier for vehicles running. The influence may be clearer for heavy vehicles.

The paper is limited by the analysis based on three roundabouts, and it is necessary to increase number of sites with more variation in geometry in order to generalize their impact of gap parameters.

Table-2 Result of t_c [sec], (sample size(acc,rej))

	A	B	C	D	E
Towa-cho	5.1 (73,55)	4.8 (64,75)	5.4 (62,56)	5.1 (73,76)	5.7 (71,66)
Hitachi-taga	5.3 (28,49)	-	4.5 (26,31)	4.5 (43,92)	-
Itoman	5.5 (63,61)	5.0 (60,58)	5.1 (65,58)	6.0 (62,181)	4.6 (58,88)

Table-3 Result of t_f [sec], (sample size)

	A	B	C	D	E
Towa-cho	2.8(65)	3.0(60)	2.8(60)	2.7(59)	2.8(30)
Hitachi-taga	2.6(44)	-	2.1(12)	2.2(29)	-
Itoman	2.2(49)	2.4(45)	2.7(50)	2.4(49)	2.4(40)

Table-4 Result of τ [sec], (sample size)

	AB	BC	CD	DE	EA
Towa-cho	2.1(47)	2.2(49)	2.0(51)	2.2(49)	2.2(53)
Hitachi-taga	2.2(65)	-	2.6(52)	2.1(147)	-
Itoman	2.1(45)	1.8(49)	1.9(48)	2.0(51)	1.8(50)

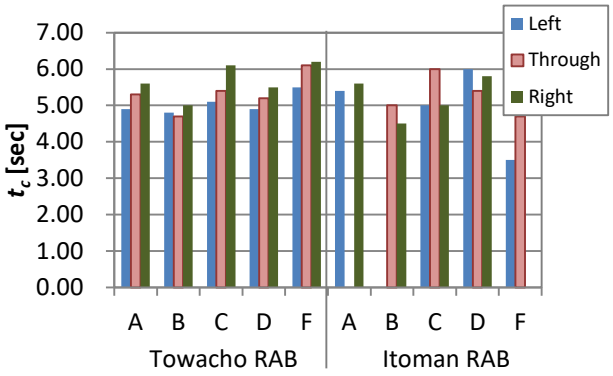


Fig-3 Respective t_c of each entry by OD (t_c of Blank parts and Hitachitaga RAB cannot be obtained due to lack of sample)

Table-5 Relationship between τ and geometry parameters

	Coefficient	t-statistic
Const.	1.90	14.61**
φ_e	1.15×10^{-2}	2.78*
φ_o	7.13×10^{-3}	4.50**
R^2	0.806	

*: Significant Level < 5% **: Significant Level < 1%

Table-6 Relationship between τ and geometry parameters

	Coefficient	t-statistic
Const.	2.93	4.25
D	-2.08×10^{-2}	-2.97*
R^2	0.482	

*: Significant Level < 5% **: Significant Level < 1%

References

1) Roundabout Manual, Japan Society of Traffic Engineers, 2016.
2) Kimber, R: Traffic Capacity of Roundabouts, Transportation and Research Laboratory, Laboratory Report LR942, Crawthorne, Berkshire, U.K., 1980.
3) Highway England, Design Manual for Roads and Bridges, Geometric Design of Roundabouts, 1992.
4) Kanbe N, et al Analysis on Influence of Geometric Design on Gap Parameters At Roundabout, the 54th Research Presentation of Infrastructure Planning and Management, 2016.