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**ASSESSMENT OF PSYCHOTECHNICAL PARAMETERS OF
VEHICLE DRIVERS ON ROUNDABOUT HITACHI TAGA, JAPAN**

Summary. The assessment of psychotechnical parameters (that is, critical gaps and follow-up times) of vehicle drivers at roundabout Hitachi Taga, Ibaraki Prefecture in Japan was presented in this paper. The basis for this assessment were empirical data from measurements in the field, made in two different years. The first field measurement took place two years after the construction of the roundabout in 2014, and the second one in 2019. The results comparison of 2014 and 2019 was aimed at assessing possible changes in the psychotechnical parameters in time. This assessment was carried out as one of the element of the project titled “Analysis of the applicability of the author's method of roundabouts entry capacity calculation developed for the conditions prevailing in Poland to the conditions prevailing at roundabouts in Tokyo (Japan) and in the Tokyo surroundings”, financed by the Polish National Agency for Academic Exchange.

Keywords: roundabouts, critical gap, follow-up time, road traffic engineering, transport

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1. INTRODUCTION

The popularity of roundabouts in various countries of the world has contributed to the conduct of multi-faceted studies related to this type of intersections [4, 5, 12, 13, 18]. However, in Japan, roundabouts are not as popular as in European countries, Australia or the USA. The vast majority of intersections operating in Japan are intersections with traffic lights. The proper functioning of intersections with traffic lights depends on the adjustment of the traffic light program to the load of vehicle streams of particular relations at the entries as well as the coordination of the operation of the traffic lights in the intersections network. In the absence of such arrangements, vehicle drivers face delays, increase fuel consumption, emissions, dissatisfaction and frustration. In this situation, an alternative solution may be the reconstruction of the intersection to the roundabout. Although around 140 roundabouts have been established so far throughout Japan (data according to [7]), they are becoming popular, hence, a subject for research [1, 2, 3, 6, 10, 11, 16, 20, 21]. According to the Ministry of Land, Infrastructure, Transport and Tourism in Japan [14], the results of the survey carried out on a group of 2033 respondents (vehicle drivers, cyclists and pedestrians) indicates improvement of road traffic conditions in the area of the intersection after the reconstruction of the intersection to the roundabout (according to 70% of respondents). On the other hand, 10% of respondents expressed contrary views on the reconstruction of intersections to roundabouts faulting the negative features of the roundabouts. The results of the same survey indicate that 70% of vehicle drivers confirm the improvement of road traffic safety after the reconstruction of the intersection to the roundabout. Alternatively, in a group of cyclists and pedestrians, only 6% of respondents confirmed that the reconstruction of the intersection to the roundabout resulted in improved road traffic safety conditions.

The assessment of psychotechnical parameters (critical gaps and follow-up times) of vehicle drivers at roundabout Hitachi Taga, Ibaraki Prefecture in Japan is in this paper. The basis for this assessment is empirical data from measurements in the field, made in two different years. The first field measurement took place two years after the construction of the roundabout in 2014, and the second one in 2019. The results comparison between 2014 and 2019 is aimed at assessing possible changes in the psychotechnical parameters in time. This assessment was carried out as one of the element of the project titled “Analysis of the applicability of the author's method of roundabouts entry capacity calculation developed for the conditions prevailing in Poland to the conditions prevailing at roundabouts in Tokyo (Japan) and in the Tokyo surroundings”, financed by the Polish National Agency for Academic Exchange.

2. RECOMMENDATIONS OF THE MINISTERS OF LAND, INFRASTRUCTURE, TRANSPORT AND TOURISM IN JAPAN IN THE AREA OF THE APPLICATION OF ROUNDABOUT

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan have determined road-traffic conditions for road intersections with possibilities of likely conversion into roundabouts. These recommendations indicate that the intersection could be rebuilt into a roundabout when traffic volume at such intersections is less than 10,000 vehicles per day. However, in a situation where the traffic volume exceeds 10,000 per day, then the traffic volumes on each intersection inlet and outlet and traffic volumes in rush hours would be

subject to further detail analysis). Furthermore, MLIT gives recommendations for the design of roundabouts. There are [15]:

- the roundabout external diameter should be selected considering vehicle trajectory in the roundabout area, taking into account the size of different vehicles, entry angles of the roundabout and the possibility of the appropriate roundabout central island project,
- in the case of significant values of traffic volumes of pedestrians and cyclists, particular attention should be paid to the design of appropriate road traffic protection devices for pedestrians, cyclists and vehicle drivers,
- the roundabout shape should be circular or a shape similar to a circle,
- the possibility of designing zones/parking spaces in the area of the roundabout should be excluded,
- it is advisable that dividing islands be placed at entries of the roundabout,
- the construction of the dividing islands on the roundabout entries should not impair visibility conditions for vehicle drivers in the roundabout area,
- the roundabout inlets and outlets should be designed in such way that enable safe and smooth vehicular movement flow to and from the roundabout circulatory roadway,
- circulatory roadway width, as well as the roundabout inlet lane width and outlet lane width, should be adapted to the dimensions of particular vehicle types moving on the roundabout and should provide free and safe movement on the roundabout,
- apron should be clearly separated from the roundabout circulatory roadway, so that users can easily differentiate between them,
- all necessary road traffic safety devices should be designed in the area of the roundabout.
- if necessary, lightings should be installed in the area of the roundabout, including the place on the roundabout central island,
- it is desirable to use road traffic signs in the form of vertical markings: 105C, 108 A, 108 2-A, 201,
- it is desirable to use the horizontal markings in the forms of lines: 103 and 107.

3. ROUNDABOUT AT HITACHI TAGA STATION

Hitachi Taga roundabout was built in 2012 in front of the Hitachi-Taga Station in Hitachi, Ibaraki Prefecture (Fig. 1). It is a four-leg, single lane roundabout. After handing over the roundabout for public use, employees of the municipal authorities and police officers in Hitachi were assigned to distribute awareness leaflets to the residents about the new road traffic rules for moving in the area of roundabout. Moreover, the Metropolitan Police Department in Hitachi, after the construction of the roundabout, informed the public about the new road traffic rules of moving around the roundabout as part of its road safety improvement program. Vertical road sign "circular movement" was placed at roundabout entries with the intention to inform vehicle drivers about the circular nature of traffic on the roundabout³. This type of marking differs from that used in Poland. In Poland, obligatorily on roundabout

³ Roundabouts in Japan have been previously equipped with stop signs and one-way signs, but drivers in Japan being unfamiliar with roundabouts and with circular intersections in general, often went the wrong way. In Tokyo, the first roundabout road sign, comprising of three white arrows on a blue background, appeared at a roundabout in the residential area of Sakuragaoka in suburban Tama. At roundabouts with the road sign, drivers are required to slow down and proceed in a clockwise manner, hence, give way to road traffic that is already in the circulatory roadway of the roundabout, and exit to the left using blinkers.

entries, a set of road signs is required: "give way to the right of way" (A-7) and "circular motion" (C-12).



Fig. 1. Roundabout in Hitachi, Ibaraki Prefecture (Japan)

a) general view, b) detailed view

Source: [17]

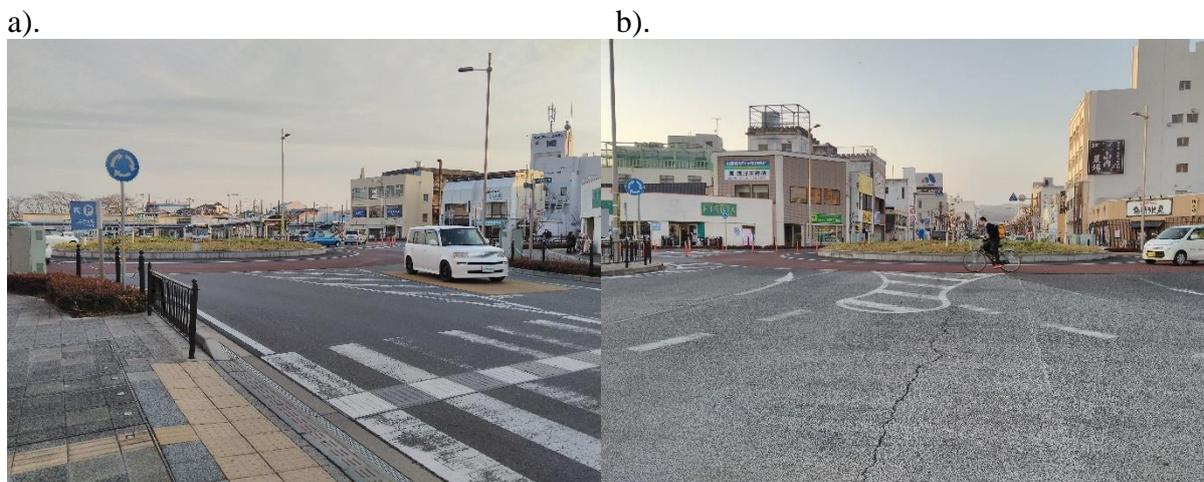


Fig. 2. Roundabout in Hitachi, Ibaraki Prefecture (Japan)

a), b) vertical marking on the roundabout entries (road sign "circular motion")

4. ASSESSMENT OF PSYCHOTECHNICAL PARAMETERS OF VEHICLE DRIVERS ON HITACHI TAGA ROUNDABOUT, JAPAN.

Assessment of psychotechnical parameters; critical gap⁴ (t_g) and follow-up time⁵ (t_f), of vehicle drivers on Hitachi Taga roundabout were made based on the measurements made in

⁴ Critical gap for vehicle drivers at roundabout entry (t_g) - this is the gap value between vehicles on a roundabout circulatory roadway, at which each gap equal or greater will be used on average from the statistical point of

October 2014 and in February 2019. In 2014, Kang and Nakamura carried out measurements in the field and the research results are presented in this paper [9]. In 2019, measurements in the field were carried out as a part of the project titled "Analysis of the applicability of the author's method of roundabouts entry capacity calculation developed for the conditions prevailing in Poland to the conditions prevailing at roundabouts in Tokyo (Japan) and in the Tokyo surroundings" [19]. The comparison of research results from 2014 and 2019 is to evaluate possible changes in the vehicle drivers' psychotechnical parameters in time. Such assessment provides answers to the question of whether the 7-year establishment of the roundabout changed the driving dynamics/behaviour of vehicle drivers. Table 1 presents the results of the critical gaps measurements obtained in 2014. These data represent critical gaps values with various combinations of vehicles belonging to different vehicle groups. Critical gap in the ideal road and traffic conditions represents such value of gap between two passenger cars on a roundabout circulatory roadway, which was accepted by the average (from a statistical point of view) of the passenger car driver from roundabout entry. The remaining critical gaps values presented in Table 1 illustrates the combination of various vehicle types. In Table 1, the circulating vehicles and entry vehicles were denoted as (c_1 , c_2) and (e_1 , e_2). Moreover, P and H represent passenger cars and heavy vehicles, respectively. Critical gaps are recorded by the form of f. ex.: $c_1c_2 - e_1$. Based on the above, the combination of various types of vehicles analysed during the research are: PP-P, HP-P, PH-P, PP-H, where: PP-P represent the critical gap in the ideal road and traffic conditions.

Tab. 1

The values of critical gaps of all combination of various vehicle types from the measurements carried out in 2014

Combination type	PP-P	HP-P	PH-P	PP-H	HH-P	HP-H	PH-H	HH-H
t_g [s]	4.7	5.9	5.1	5.5	6.1	7.5	6.6	8.0

Source: own, based on [9]

On the other hand, Table 2 presents the results of critical gaps values obtained from the measurements conducted in 2019. Critical gaps values presented in Table 2 also takes into account various combinations of different vehicle types.

view, the ability of the vehicle driver from roundabout entry to perform the maneuver of entering into the roundabout circulatory roadway, while each gap with smaller value makes it impossible to perform the intended maneuver, therefore, will not be used. Critical gap for vehicle drivers at roundabout entry is not a constant value. Critical gap has different values for different vehicle drivers and for each individual vehicle driver at different time. Critical gap is a random variable, the value of which depends on characteristics of the human and vehicle, from the geometric and traffic conditions likely characterised by probability distributions.

⁵ Follow-up time (t_f) - expresses the time interval between the passing of the first vehicle from the roundabout entry, through the edge of the roundabout and passing the next vehicle from the roundabout entry using the same gap in the traffic stream on the circulatory roadway. If the gap between the vehicles moving on the circulatory roadway allows for the entering of other vehicles from the queue on the roundabout entry, then they pass through the edge of the roundabout at intervals t_f one after the other. With a very small traffic volume on the roundabout circulatory roadway, follow-up times t_f mainly decides the roundabout entry capacity value.

Tab. 2

The values of critical gaps of all combination of various vehicle types from the measurements carried out in 2019

Combination type	PP-P	HP-P	PH-P	PP-H	HH-P	HP-H	PH-H	HH-H
t_g [s]	4.7	6.0	4.9	5.3	6.4	7.1	7.0	7.8

Source: own research

Analysing the obtained results, it can be concluded that critical gaps values from the measurements from 2014 and 2019 do not differ significantly from each other. Confirmation of this fact was obtained by carrying out Wilcoxon matched-pairs test. Wilcoxon matched-pairs test was used to assess the difference between pairs of average critical gaps values derived from the measurements carried out in 2014 and 2019, that is, difference $d_i = \bar{t}_{g-2014-i} - \bar{t}_{g-2019-i}$ for each "i" investigated cases of combination of vehicles belonging to various group of vehicles. This difference was used to verify the hypothesis that the median value θ_o for this difference in the studied population is equal zero (where: θ_o it is median value d_i in the studied population). The zero hypothesis was formulated as: $H_0 : \theta_o = 0$, which means that the median differences between the average values of t_g from measurements in 2014 and the average values of t_g from measurements in 2019 in population is equal zero. The alternative hypothesis was formulated as: $H_1 : \theta_o \neq 0$, which means that median differences between the average values of t_g from measurements in 2014 and the average values of t_g from measurements in 2019 in the population is different than zero. The level of significance was adopted as $\alpha = 0.05$. As a result of a comparison of value $p = 0.6342$ from Wilcoxon test based on statistics T with the level of significance equal $\alpha = 0.05$ concluded that $p > \alpha$. Thus, there is no reason to reject the H_0 hypothesis of median differences between average values of t_g from the measurements in 2014 and average values of t_g from the measurements in 2019. This means that there is no statistically significant difference in average values of critical gaps from the measurements carried out in 2014 and 2019.

A similar results comparison was made for follow-up times obtained from the measurements from 2014 and 2019. The research results between 2014 and 2019 are presented in Table 3 and Table 4, respectively. The data represents the average values of follow-up time for:

- passenger cars (P),
- heavy vehicles (H),
- buses (B).

Tab. 3

The values of follow-up times for various vehicle types from measurements carried out in 2014

Combination type	P	H	B
t_g [s]	3.00	3.90	4.10

Source: own, based on data [8]

Analysing the obtained results, it can be concluded that the follow-up times from the measurements carried out in 2014 and 2019 do not differ significantly. The results obtained in 2019 have slightly lower values than the values obtained in 2014, which indicates an increase in the vehicle drivers dynamic movement in traffic streams in the roundabout area. However, the difference is similar to the case of critical gaps with little statistically significant result, which was confirmed carrying out the Wilcoxon matched-pairs test. The graphical comparison of the values of critical gaps for all combination of various vehicle types as well as comparison of the values of follow-up times from the measurements carried out in 2014 and 2019 are presented in Fig. 3 and Fig. 4.

Tab. 4

The values of follow-up times for various vehicle types
from measurements carried out in 2019

Combination type	P	H	B
t_g [s]	2.97	3.80	4.00

Source: own research

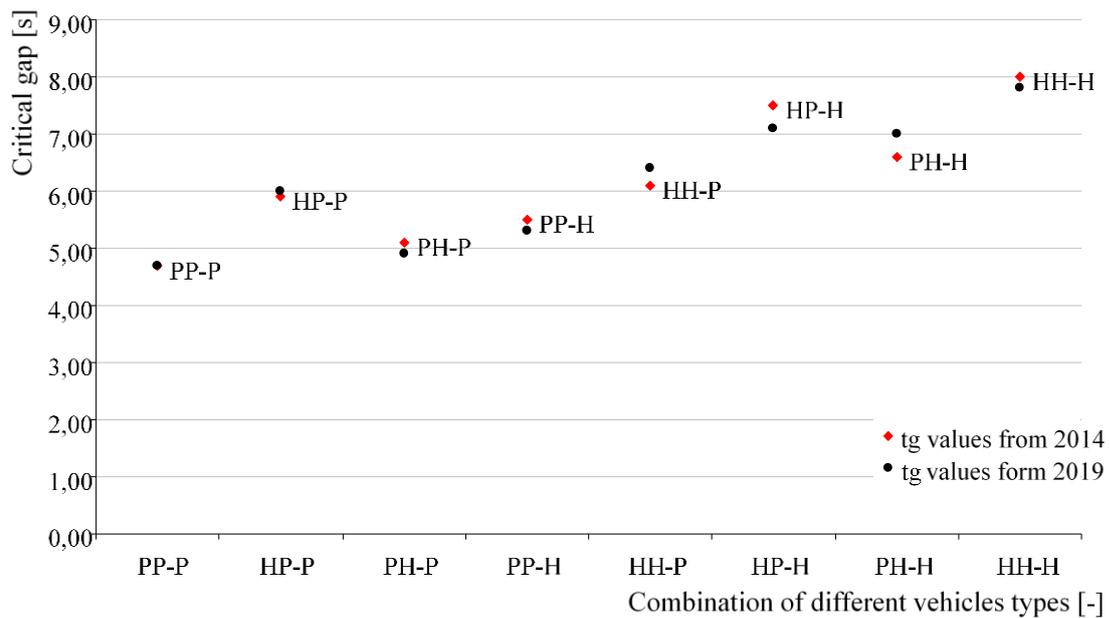


Fig. 3. Results comparison – critical gaps from measurements carried out in 2014 and 2019

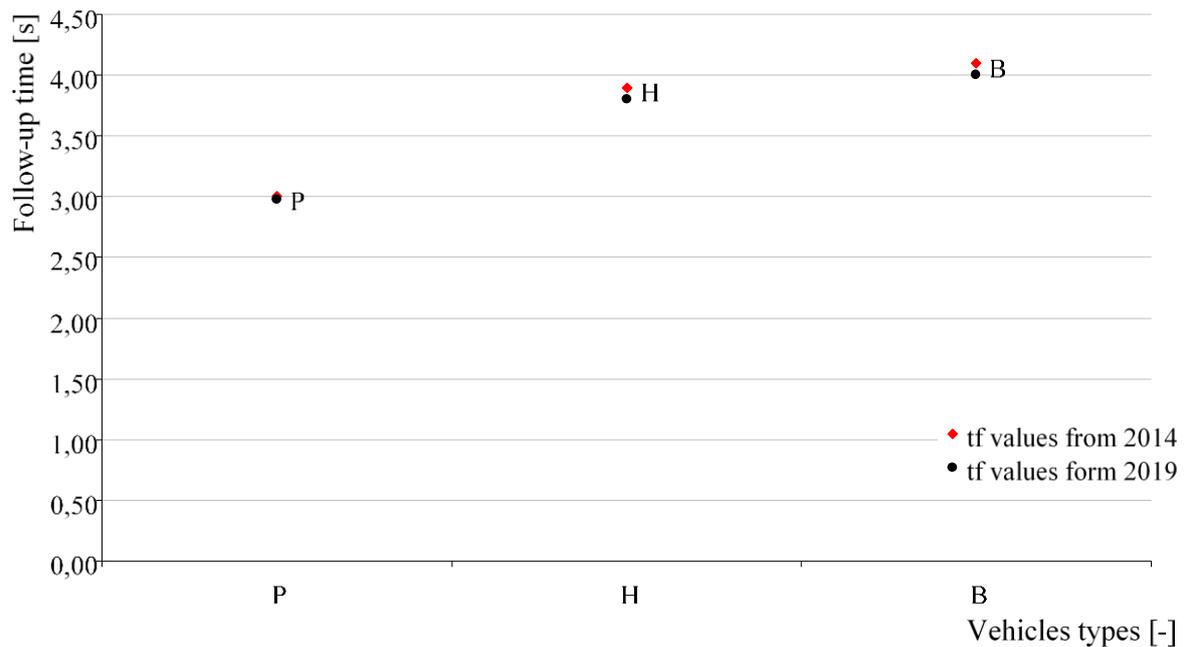


Fig. 4. Results comparison – follow-up times from measurements carried out in 2014 and 2019

In the final stage of our research, we checked how roundabout entry capacities change using the vehicle drivers psychotechnical parameters from the measurements carried out in 2014 and 2019. The results of this comparison are shown in Fig. 5. As expected, the differences in calculated capacities were small and amount to 1.00%. According to data from 2019, capacity value was higher by 1.00 % more than that of 2014.

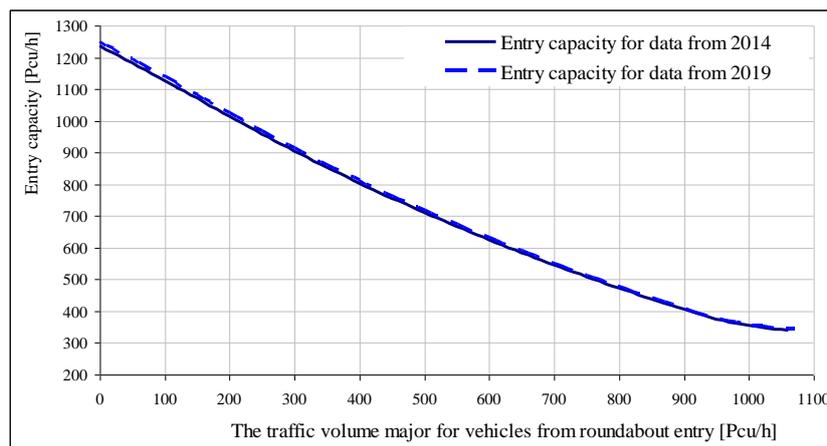


Fig. 5. Comparison of roundabout entry capacity calculated based on psychotechnical parameters data obtained from the measurements from 2014 and 2019

5. CONCLUSIONS

Presented in the paper is the assessment of psychotechnical parameters of vehicle drivers on roundabout Hitachi Taga in Japan, which leads to the conclusion that within five years, the values of vehicle drivers psychotechnical parameters, that is, critical gaps and follow-up times have not changed significantly. Although, the results of critical gaps and follow-up times obtained in 2019 have slightly lower values than the values obtained in 2014, which indicate a slight increase of vehicle drivers dynamic movement in traffic streams in the roundabout area. However, this difference, both, in case of critical gaps and follow-up times is not statistically significant, this was confirmed carrying out the Wilcoxon matched-pairs test.

This means that drivers behaviours in the analysed roundabout area have not changed significantly. Currently, vehicle drivers move in the same similar way as they did in 2014. Lack of significant differences in the vehicle drivers psychotechnical values entails insignificant changes in the roundabout entry capacity values, which are only about 1.00% higher than the capacity calculated with psychotechnical parameters data from 2014.

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