The Comparison of Models for Follow-up Headway at Roundabouts

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Abstract. One of the basic parameter used for roundabout entry capacity calculation is follow-up headway. This parameter beyond critical headway and traffic volume on roundabout roadway major for vehicle drivers from entry determines roundabout entry capacity. The comparative analysis of models and studies on follow-up headway estimation have been presented in this article. The analysis were made for single lane, two lane and turbo roundabouts. The largest number of models and studies of follow-up headway parameter refers to single lane roundabouts. The least studies were devoted to values of follow-up headway parameter at turbo roundabouts due to the fact that this is still relatively a new type of roundabout in compare with single lane or two lane roundabouts.

Keywords: Roundabouts · Follow-up headway · Gap acceptance theory · Road traffic engineering

1 Introduction

In recent years roundabouts are very popular kind of intersection. They are subject of multifaceted scientific research concerning both considerations on microscopic level f.ex. like their performance, capacity, safety (f.ex.: [1–10]) and also considerations on macroscopic level as element of the transport systems [11–19]. Due to the high level of traffic safety roundabouts are willingly used as a part of transport networks in urban area and outside urban area. The roundabouts popularity resulted in the development of models and methods for mapping behavior of traffic streams (vehicle driver, pedestrians, cyclists) on roundabouts (f.ex: [20–29]).

In models intended to roundabout entry capacity calculations based on gap acceptance theory the critical headway and follow-up headway are the basic parameters in vehicle drivers decision-making process at roundabout entry. These parameters usually represent the average behaviors in vehicle drivers population and together with the headway distribution between vehicles on main roadway of roundabout decides about the degree of accuracy of roundabout entry capacity determination.

According to literature [30] the follow-up headway (t_f) is defined as the time between the departure of first (previous) vehicle from the roundabout entry and the departure of the next vehicle using the same major-street headway under a condition of queuing on the roundabout entry. If the distance between vehicles in traffic stream on main roadway of roundabout allows for entry of further vehicles from the queue, they are passing through the edge of the roundabout roadway at follow-up headway one

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after another. At very low traffic volume on main roadway of roundabout the value of follow-up headway mainly decides about the entry capacity. According to Polish recommendations [30] setting for the roundabout capacity calculation the follow-up headway values the type of roundabout, roundabout external diameter and number of entry lanes are taking account.

In case of assumption that on roundabout entry is queue of vehicles and vehicle drivers from this queue use the same gap between vehicles moving on main roadway of roundabout the follow-up headway value can be calculated from equation:

$$t_f = t_f^{next} - t_f^{previous} \; [s] \tag{1}$$

where:

t_f - follow-up headway [s],

t_f^{next} - crossing time the edge of the roundabout roadway by next vehicle driver [s],

$t_f^{previous}$ - crossing time the edge of the roundabout roadway by previous vehicle driver [s].

Many scientific studies provide results from measurements of follow-up headway from real data at roundabouts. In practice, the value of parameter t_f is frequently represented as the average value (specifying also with value of the standard deviation) or as a median. In different scientific papers the minimum and maximum values are also presented. In case of two lane roundabouts the follow-up headway values are stated separately for the right and left entry lane as well as for the inner and outer lane on roundabout roadway. Whereas in case of turbo roundabouts further decomposition of t_f values occurs because of different types of traffic control on entry and on roundabout main roadway area, i.e. one or two entry lanes and one or two circulating lanes.

The analysis in the regards of scientific papers related to determination of follow-up headway values for vehicle drivers on single lane, two lane and turbo roundabouts have been presented in this article. In view of a very large collection of published studies connected with this issue, the analysis in this article is focused on the most important, most popular models and the latest studies in this area.

2 The Comparison of Models for Follow-up Headway at Roundabouts

In scientific literature can be found a lot of synthetic reviews on gap acceptance parameters for roundabouts, f.ex. [31–35]. According to research the values of follow-up headways may depends on roundabout geometry, number of traffic lanes on entry and on main road of roundabout, vehicle type, the presence of bunched vehicles on main roadway and many other factors. The follow-up headway value also depend on combination of vehicle types in the queue at the entry (i.e. passenger cars and heavy vehicles). In many scientific papers the follow-up headway value is defined for

passenger cars, less frequently for another type of vehicle like heavy vehicles, bikes, buses etc. The selected studies characterizing the follow-up headway for drivers at single lane roundabouts entries are presented in Table 1.

Table 1. Comparison of follow-up headway models for single lane roundabouts.

Country	Author	The model/value of follow-up headway parameter [s]
Germany	W. Brilon [36]	For small roundabouts ($13 \leq D_z \leq 26$ m) and single roundabouts ($26 \leq D_z \leq 40$): $t_f = 2.84 + \frac{2.07}{D_z}$, $t_f \in \langle 2.89; 3.00 \rangle$, (Average value = 2.94)
	N. Wu [37]	Average value = 2.88
USA	HCM 2010 [38]	Average value = 3.20
	NCHRP Report 572 [39]	$t_f \in \langle 2.6; 4.3 \rangle$, (Average value = 3.20)
	HCM 2016 [40]	Average value = 2.60
	Y. Mereszczak et al. [41]	$t_f \in \langle 2.6; 3.0 \rangle$, (Average value = 2.80)
	F. Xu, Z. Tian [42]	$t_f = 2.38 - 0.000071 \cdot Q_{nwl,}$ (Average value = 2.50)
Canada	J. Dahl, Ch. Lee [43]	$t_f \in \langle 2.10; 4.20 \rangle$, (Average value = 3.15)
The Netherlands	L. Fortuijn [44]	Average value = 2.10
Australia	L. Ren, Q. Xiaobo [45]	$t_f \in \langle 2.35; 2.75 \rangle$, (Average value = 2.55)
	X. Qu [46]	Average value = 2.76
Portugal	L. Vasconcelos, A. Seco, A. Silva [47]	$t_f \in \langle 2.10; 2.30 \rangle$, (Average value = 2.20)
Spain	M. Romana [48]	$t_f \in \langle 1.65; 1.75 \rangle$, (Average value = 1.70)
Denmark	P. Greibe [49]	Average value = 3.00
Italy	A. Gazzarri et al. [50, 51]	$t_f \in \langle 2.52; 2.76 \rangle$, (Average value = 2.63)
Slovenia	T. Tollazi [52]	Average value = 2.90
Poland	J. Chodur [53]	$t_f = 0.31 \cdot D_z - 0.0044 \cdot D_z^2 + 0.00052 \cdot wm - 2.59$ (Average value = 2.85)
	E. Macioszek [54]	For 22 m $\leq$ D_z $\leq$ 45 m, 4 $m \leq l_{jr} \leq 8$ m: $t_f = 3.64 - 0.02 \cdot D_z - 0.03 \cdot l_{jr}$ (Average value = 2.79)

where:
D_z - roundabout external diameter [m],
Q_{nwl} - circulating flow [pcu/h],
wm - city size determined by the number of inhabitants (19.60-740.00 thousands of inhabitants),
$\overline{V}$ - the average vehicle speed [km/h],
l_{jr} - the width of the roundabout roadway [m],
t_g - critical headway [s].

On the basis of data included in Table 1 can be concluded the differences between the proposed follow-up headways values. These differences are the results of various vehicle driver behavior in different countries in the world as well as result from the different techniques and methods of follow-up time headway parameter measurements. The comparison of average values of follow-up headways for single lane roundabouts proposed by different authors in different countries of the world have been presented on the Fig. 1.

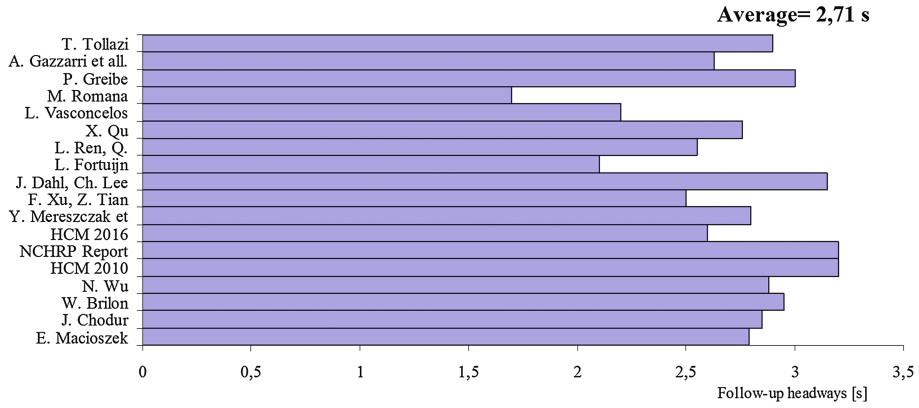

Fig. 1. The average values of follow-up headways for single lane roundabouts

On the basis of Fig. 1 can be concluded that the average value of follow-up headway for all models is equal 2.71 s. Values below the average can be observed f.ex. in such countries as Italy, Spain, Portugal, USA (according HCM 2016), Netherlands, Australia. Whereas values higher than the average value can be observed f.ex. in Germany, Canada, Denmark, Slovenia and Poland. It should be noted that according most recent research published in HCM 2016 average value of follow-up headway is equal 2,60 s, while previous USA studies (f.ex. HCM 2010, NCHRP Report 572, F. Xu, Z. Tian) indicate for a slightly higher average values of follow-up headway for single lane roundabouts. The decrease in average value of follow-up headway confirms that vehicle drivers in USA have become accustomed with roundabouts and they drive firmly on this type of intersections.

Besides, the potential impact of follow-up headway value on single lane roundabout entry capacity was examined by varying the parameter t_f from minimum to maximum values under different circulating traffic flows (Q_{nwl}). The follow-up headway value change between 1.70–3.20 s. This t_f values were adopted on the basis of various authors research presented in Table 1 (see Fig. 2). Critical headway was assumed to be constant. As can be seen from Fig. 2 single lane roundabout entry capacity is higher when vehicle drivers from queue at roundabout entry moving on main roadway of roundabout with smaller follow-up headway values. Consequently, accurate determination of follow-up headway value is very important because can improves the accuracy of roundabout entry capacity calculation.

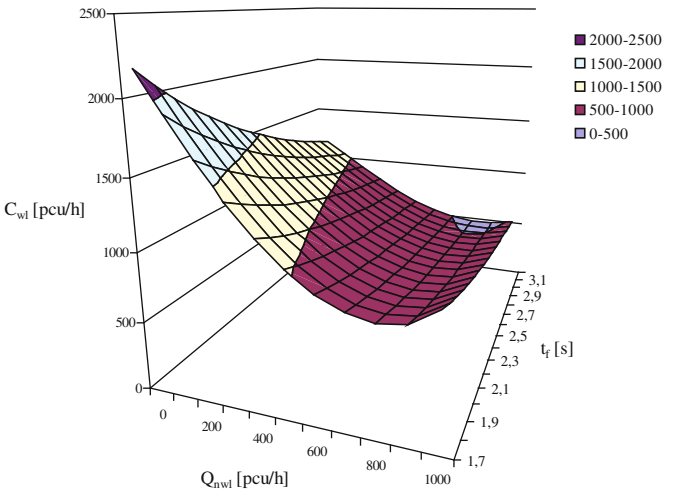

Fig. 2. The change in single lane roundabout entry capacity calculated with different values of follow-up headways

In scientific studies can be found slightly less number of follow-up headways models and results for two lane roundabouts then in case of single lane roundabouts. The comparison of selected follow-up headway results for two lane roundabout have been presented in Table 2. Base on the Table 2 can be concluded that part of these results were defined with accuracy of roundabout entry lane and other part applies only to value of follow-up headway for entire roundabout entry.

The comparison of average values of follow-up headways for two lane roundabouts proposed by different authors in different countries of the world have been presented on the Fig. 3. Based on the Fig. 3 can be concluded that average values of follow-up headway for vehicle drivers from right and left entry lane are respectively 2.68 s and 2.72 s. It means that vehicle drivers from the right entry lane moving on main roadway of roundabout faster, with shorter follow-up headways then vehicle drivers from the left entry lane.

One of new types of roundabouts like turbo roundabouts were already development and implemented in many countries in the world. In case of turbo roundabouts the follow-up headway value depend on traffic control in entry and roundabout main roadway area. In practice at turbo roundabouts can be distinguish few different type of traffic control in entry and roundabout main roadway area i.e. one or two entry lane and one or two circulating lane. The comparison of follow-up headway values for turbo roundabouts have been presented in Table 3. Due to the fact that turbo roundabouts are relatively new type of intersection, there are little research results and models for follow-up headways. There is a definite need for further research on follow-up headways values at turbo roundabouts at different variants of traffic control.

Table 2. Comparison of follow-up headway results for two lane roundabouts.

Country	Author	The value of follow-up headway parameter [s]
Germany	W. Brilon [36]	$t_f \in \langle 2.20; 2.90 \rangle$, (Average value = 2.55),
	N. Wu [37]	Average value = 2.88
USA	HCM 2010 [38]	Left lane average = 3.20, Right lane average = 3.20
	HCM 2016 [40]	Left lane average = 2.66, Right lane average = 2.53
	F. Xu, Z. Tian [42]	Left lane average = 2.30, Right lane average = 2.20
	NCHRP Report 572 [39]	Left lane = 3.1-4.7, (Average value = 3.4), Right lane = 2.7-4.4, (Average value = 3.1)
Canada	J. Dahl, Ch. Lee [43]	$t_f \in \langle 1.60; 5.00 \rangle$, (Average value = 3.30)
Portugal	L. Vasconcelos, A. Seco, A. Silva [47]	$t_f \in \langle 1.94; 2.78 \rangle$, (Average value = 2.36)
Switzerland	N. Leemann, G. Santel [55]	$t_f \in \langle 2.27; 2.63 \rangle$, (Average value = 2.45)
Denmark	P. Greibe [49]	Average value = 2.60
	O. Hagring, N. Rouphail, H. Sorensen [56]	Average value = 2.79
Italy	A. Gazzarri, M. Martello, A. Pratelli, R. Souleyrette [50]	Left lane average = 2.65, Right lane average = 2.64, Minimum value = 2.16, Maximum value = 3.10
The Netherlands	L. Fortuijn [44]	$t_f \in \langle 2.24; 2.26 \rangle$, (Average value = 2.25)
Poland	Polish Quidelines [30]	$t_f \in \langle 2.90; 3.30 \rangle$, (Average value = 3.10)
	E. Macioszek [54]	Left lane average = 3.20, Right lane average = 3.20

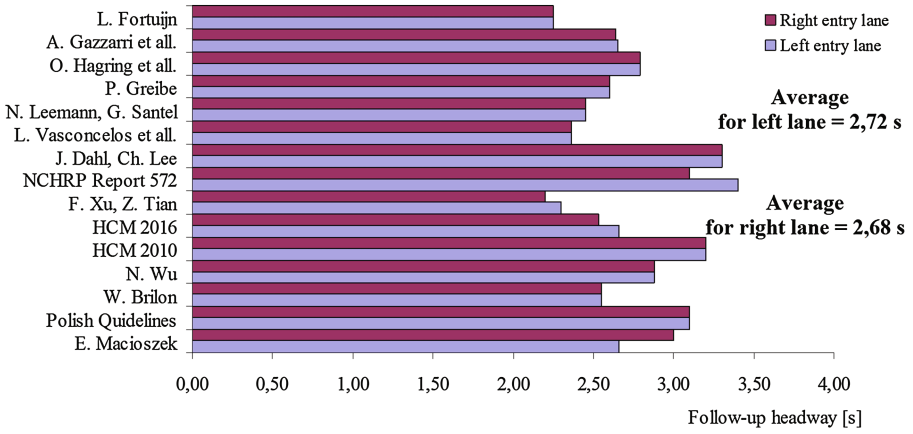

Fig. 3. The average values of follow-up headways for two lane roundabouts

Table 3. Comparison of follow-up headway results for turbo roundabouts.

Country	Author	The value of follow-up headway parameter [s]
The Netherlands	L. Fortuijn [44]	Right entry lane at major entry: average 2.13 Left entry lane at major entry: average 2.25 Depending on traffic control
Germany	W. Brilon, L. Bondzio, F. Weiser [57]	$t_f \in \langle 2.50; 2.80 \rangle$ Depending on traffic control
Poland	E. Macioszek [54]	Right lane: 1.48-4.76 (average 2.21) Left lane: 1.24–5.08 (average 2.35) Depending on traffic control

3 Summary

The synthesis from scientific studies about follow-up headway values for single lane, two-lane and turbo roundabouts have been presented in this article. The largest number of models and studies of t_f parameter refers to single lane roundabouts. This is connected with a large number of such type of roundabouts developed in different countries of the world. Because of their great advantages in the context of road traffic safety in many countries single lane roundabouts are the most numerous group among roundabouts. By far the least studies were devoted to values of t_f parameter at turbo roundabouts due to the fact that this is still relatively a new type of roundabout in compare with single lane or two lane roundabouts. There is a definite need for further research on follow-up headways values at turbo roundabouts at different variants of traffic control.

The values of follow-up headway for particular types of roundabouts are different depending on country and individual studies. These differences have an influence on calculated roundabout entry capacity. In addition, in many studies in calculations the constants values of follow-up headway are recommended (which represent an average value from all observed vehicle drivers) instead functions which enable adjustment the value of follow-up headway to traffic and geometric features f.ex. like roundabout external diameter, number of traffic lanes, lanes width, entry radius etc. In turn, assuming in roundabout entry capacity calculations average value of follow-up headway (and average value of critical headway) causes inaccuracy in calculations and averaging the results.

References

1. Macioszek, E., Akçelik, R.: A comparison of two roundabout capacity models. Paper Prepared for the 5th International Roundabout Conference. Transportation Research Board, USA (2017). http://www.sidrasolutions.com/Resources/Articles

2. Macioszek, E.: Relationship between vehicle stream in the circular roadway of a one-lane roundabout and traffic volume on the roundabout at peak hour. In: Mikulski, J. (ed.) Telematics - Support for Transport. CCIS, vol. 471, pp. 110–119. Springer, Heidelberg (2014)
3. Macioszek, E.: Turbo-roundabouts signing and marking – current situation in Poland. Arch. Transp. Syst. Telemat. **6**(1), 26–30 (2013)
4. Szczuraszek, T., Macioszek, E.: Analiza Rozkładów Odstępów Czasu Pomiędzy Pojazdami na Obwiedni Małych Rond. Drogi i Mosty **3**, 89–99 (2010)
5. Macioszek, E.: Analysis of the effect of congestion in the lanes at the inlet to the two-lane roundabout on traffic capacity of the inlet. In: Mikulski, J. (ed.) Activities of Transport Telematics. CCIS, vol. 395, pp. 97–104. Springer, Heidelberg (2013)
6. Macioszek, E.: The influence of motorcycling and cycling on small one-lane roundabouts capacity. In: Mikulski, J. (ed.) Modern Transport Telematics. CCIS, vol. 239, pp. 291–298. Springer, Heidelberg (2011)
7. Macioszek, E.: The application of HCM 2010 in the determination of capacity of traffic lanes at turbo roundabout entries. Transp. Probl. **11**(3), 77–89 (2016)
8. Macioszek, E.: Analiza Możliwości Zastosowania Metody HCM 2010 do Szacowania Przepustowości Pasów Ruchu na Wlotach Rond w Polsce. Prace Nauk. Politech. Warsz. Ser. Transp. **113**, 327–340 (2016)
9. Macioszek, E.: The movement model for small roundabouts with minor roads capacity estimating. Transp. Probl. **1**, 87–94 (2007)
10. Macioszek, E.: Analysis of opportunities of using the HCM 2010 methodology for evaluation of traffic capacity at the entries to turbo roundabouts. In: Proceedings VIII International Scientific Conference Transport Problems, pp. 314–326 (2016)
11. Sierpiński, G., Staniek, M., Celiński, I.: Research and shaping transport systems with multimodal travels – methodological remarks under the green travelling project. In: 7th International Conference of Education, Research and Innovation ICERI Proceedings, pp. 3101–3107. Seville (2014)
12. Okraszewska, R., Nosal, K., Sierpiński, G.: The role of the polish universities in shaping a new mobility culture - assumptions, conditions, experience. Case study of Gdansk University of Technology, Cracow University of Technology and Silesian University of Technology. In: 7th International Conference of Education, Research and Innovation ICERI Proceedings, pp. 2971–2979. Seville (2014)
13. Sierpiński, G.: Theoretical model and activities to change the modal split of traffic. In: Mikulski J. (ed.) Transport Systems Telematics 2012. Telematics in the Transport Environment. CCIS, vol. 329, pp. 45–51. Springer, Heidelberg (2012)
14. Staniek, M.: Road pavement condition as a determinant of travelling comfort. In: Sierpiński, G. (ed.) Intelligent Transport Systems and Travel Behaviour. AISC, vol. 505, pp. 99–107. Springer, Switzerland (2017)
15. Sierpinski, G.; Staniek, M., Celinski, I.: New methods for pro-ecological travel behavior learning. In: 8th International Conference of Education, Research and Innovation ICERI Proceedings, pp. 6926–6933. Seville (2015)
16. Staniek, M.: Stereo vision method application to road inspection. Balt. J. Road Bridge Eng. **12**(1), 38–47 (2017)
17. Burdzik, R., Celiński, I., Czech, P.: Optimization of transportation of unexploded ordnance, explosives and hazardous substances - vibration issues. Vibroeng. Proc. **10**, 382–386 (2016)

18. Młyńczak, J., Burdzik, R., Celiński, I.: Research on dynamics of shunting locomotive during movement on marshalling yard by using prototype of remote control unit. In: Awrejcewicz, J. (ed.) Dynamical Systems: Theoretical and Experimental Analysis. PMS, vol. 182, pp. 279–292. Springer, Berlin (2016)
19. Celiński, I.: Transport network parameterisation using the GTAlg tool. In: Macioszek, E., Sierpiński, G. (eds.) Contemporary Challenges of Transport Systems and Traffic Engineering. LNNS, vol. 2, pp. 111–123. Springer, Switzerland (2017)
20. Macioszek, E.: Geometrical determinants of car equivalents for heavy vehicles crossing circular intersections. In: Mikulski, J. (ed.) Telematics in the Transport Environment. CCIS, vol. 329, pp. 221–228. Springer, Heidelberg (2012)
21. Szczuraszek, T., Macioszek, E.: Proportion of vehicles moving freely depending on traffic volume and proportion of trucks and buses. Balt. J. Road Bridge Eng. **8**(2), 133–141 (2013)
22. Macioszek, E., Sierpiński, G., Czapkowski, L.: Methods of modeling the bicycle traffic flows on the roundabouts. In: Mikulski, J. (ed.) Transport Systems Telematics. CCIS, vol. 104, pp. 115–124. Springer, Heidelberg (2010)
23. Macioszek, E., Sierpiński, G., Czapkowski, L.: Problems and issues with running the cycle traffic through the roundabouts. In: Mikulski, J. (ed.) Transport Systems Telematics. CCIS, vol. 104, pp. 107–114. Springer, Heidelberg (2010)
24. Macioszek, E.: Safe road traffic on roundabouts as an element assisting efficient road transportation system development in the Upper Silesia Region. In: Janecki, R., Krawiec, S., Sierpiński, G. (eds.) Contemporary Transportation Systems. Selected Theoretical and Practical Problems. The Transportation as the Factor of the Socio-economic Development of the Regions. Monograph, vol. 386, pp. 85–95. Silesian University of Technology, Gliwice (2012)
25. Macioszek, E.: Road traffic safety as an element creating mobility culture in cities. In: Janecki, R., Sierpiński, G. (eds.) Contemporary Transportation Systems. Selected Theoretical and Practical Problems. New mobility Culture. Monograph, vol. 324, pp. 61–71. Silesian University of Technology, Gliwice (2011)
26. Macioszek, E.: The road safety at turbo roundabouts in Poland. Arch. Transp. **33**(1), 57–67 (2015)
27. Macioszek, E.: Stan Bezpieczeństwa Ruchu Drogowego na Rondach Turbinowych w Polsce. Prace Naukowe Politechniki Warszawskiej. Transport. Bezpieczeństwo i Analiza Ryzyka w Transporcie, vol. 96, pp. 295–307 (2013)
28. Macioszek, E.: The passenger car equivalent factor for heavy vehicles on roundabouts. In: Janecki, R., Sierpiński, G. (eds.) Contemporary Transportation Systems. Selected Theoretical and Practical Problems. The Development of Transportation Systems. Monograph, vol. 256, pp. 127–137. Silesian University of Technology, Gliwice (2010)
29. Macioszek, E.: Analiza Prędkości Przejazdu Pojazdów Przez Skrzyżowania z Ruchem Okrężnym. Prace Naukowe Politechniki Warszawskiej. Transport. Systemy, Podsystemy i Środki w Transporcie Drogowym, Morskim i Śródlądowym, vol. 82, pp. 69–84 (2012)
30. Generalna Dyrekcja Dróg Krajowych i Autostrad: Metoda Obliczania Przepustowości Rond. Instrukcja Obliczania. GDDKiA, Warszawa (2004)
31. Giuffre, O., Grana, A., Tumminello, A.L.: Gap-acceptance parameters for roundabouts: a systematic review. Eur. Transp. Res. Rev **8**, 1–20 (2016)
32. Macioszek, E.: Analysis of significance of differences between psychotechnical parameters for drivers at the entries to one-lane and turbo roundabouts in Poland. In: Sierpiński, G. (ed.) Intelligent Transport Systems and Travel Behaviour. AISC, vol. 505, pp. 149–161. Springer, Switzerland (2017)
33. Macioszek, E., Woch, J.: The Follow-up time issue on small roundabouts. Transp. Probl. **3**, 25–31 (2008)

34. Macioszek, E.: The comparison of models for critical headways estimation at roundabouts. In: Macioszek, E., Sierpiński, G. (eds.) Contemporary Challenges of Transport Systems and Traffic Engineering. LNNS, vol. 2, pp. 205–219. Springer, Switzerland (2017)
35. Macioszek, E., Sierpiński, G. (eds.) Contemporary challenges of transport systems and traffic engineering. Selected Papers. LNNS, vol. 2. Springer, Switzerland (2017)
36. Brilon, W.: Studies on Roundabouts in Germany. Lessons Learned. http://www.ruhr-uni-bochum.de/verkehrswesen/download/literatur/Brilon_roundabouts_2011_05_29_cit.pdf
37. Wu, N.: An Universal Formula for Calculating Capacity at Roundabouts. Research Report of Institute for Traffic Engineering. Ruhr University, Bochum (1997)
38. Transportation Research Board: Highway Capacity Manual 2010. Transportation Research Board of the National Academy of Science, Washington (2010)
39. Rodegerdts, L., Blogg, M., Wemple, E., Myers, E., et al.: NCHRP Report 572. Roundabouts in the United States. Transportation Research Board, Washington (2007)
40. Transportation Research Board: Highway Capacity Manual 6th Edition. A Guide for Multimodal Mobility Analysis. Transportation Research Board of the National Academy of Science, Washington (2016)
41. Mereszczak, Y., Dixon, M., Kyte, M., Rodegerdts, L.A., Blogg, M.: Incorporating exiting vehicles in capacity estimation at single-lane U.S. roundabouts. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.508.7303&rep=rep1&type=pdf
42. Xu, F., Tian, Z.Z.: Driver behavior and gap acceptance characteristics at roundabouts in California. J. Transp. Res. Board **2071**, 117–124 (2008)
43. Dahl, J., Lee, C.: Empirical estimation of capacity for roundabouts using adjusted gap-acceptance parameters for trucks. J. Transp. Res. Board **2312**, 34–45 (2012)
44. Fortuijn, L.G.H.: Turbo roundabout. Estimation of capacity. Transp. Res. Rec. **2130**, 83–92 (2009)
45. Ren, L., Xiaobo, Q.: Impact analysis of headway distributions on single-lane roundabout entry capacity. J. Eng. Proj. Production Manag. **6**(1), 2–12 (2016)
46. Qu, X., Zhang, I.J., Wang, S., Liu, Z.: Modelling follow up time at a single lane roundabout. J. Traffic Transp. Eng. **1**, 97–102 (2014)
47. Vasconcelos, A.L.P., Seco, A.J.M., Silva, A.M.C.B.: Comparison of procedures to estimate critical headways at roundabouts. Promet Traffic Transp. **25**, 43–53 (2013)
48. Romana, M.G.: Roundabout practice and research in Spain. In: 6th International Symposium on Highway Capacity (2011)
49. Greibe, P.: Roundabout - design and capacity. In: Denmark Country report, 6th International Symposium on Highway Capacity (2011)
50. Gazzarri, A., Martello, M., Pratelli, A., Souleyrette, R.: Estimation of gap acceptance parameters for HCM 2010 roundabout capacity model applications. In: Longhurst, J.W.S., Brebbia, C.A. (eds.) Urban Transport XVIII. Urban Transport and the Environment in the 21st Century, vol. 128, pp. 309–320. WIT Press, Southampton (2012)
51. Gazzarri, A., Martello, M., Pratelli, A., Souleyrette, R.: Gap acceptance parameters for HCM 2010 roundabout capacity model applications in Italy. Civil Eng. Fac. Publ. **1**, 1–16 (2013)
52. Tollazi, T.: The contribution to the procedure of capacity determination at unsignalized prioriry controlled intersections. Promet Traffic Transp. **16**, 31–36 (2004)
53. Chodur, J.: Funkcjonowanie Skrzyżowań Drogowych w Warunkach Zmienności Ruchu. Monografia 347. Politechnika Krakowska, Kraków (2007)
54. Macioszek, E.: Modele Przepustowości Wlotów Skrzyżowań Typu Rondo w Warunkach Wzorcowych (Models of traffic capacity in roundabout inlets in ideal conditions). Open Access Library, vol. 3(21), Gliwice (2013)

55. Leemann, N., Santel, G: Two lane roundabouts. In: 9th Swiss Transport Research Conference. http://www.strc.ch/conferences/2009/Leemann.pdf
56. Hagring, O., Rouphail, N.M., Sorensen, H.A.: Comparison of capacity models for two lane roundabouts. Transportation Research Board Annual Meeting. http://citeseerxist.psu.edu/viewdoc/download?doi=10.1.1.965.8969&rep=rep1&type=pdf
57. Brilon, W., Bondzio, L., Weiser, F.: Experiences with turbo roundabouts in Germany. http://nmfv.dk/wp-content/uploads/2014/04/Experiences-with-Turbo-Roundabouts-in-Germany-Brilon-Bondzio-Weiser.pdf