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# Capacity of Single-lane Roundabouts in Hungary

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**Abstract**

Roundabouts are a prevalent type of intersection known for their potential to enhance traffic flow. Ensuring their effective design is crucial for optimizing traffic performance. This study focuses on evaluating the capacity of roundabouts, essential for both planning new installations and assessing existing ones. Field data from thirteen roundabouts in Hungary were analyzed to estimate critical gap and follow-up headway values for each entry. Employing Raff's graphical method, critical gap values were determined, while follow-up headway was calculated by averaging the time taken for two waiting vehicles to accept the same gap over eight instances. The critical gaps and follow-up headway values for all forty-one entries ranged between 2.41–3.46 s and 1.8–2.4 s, respectively. Subsequently, the Highway Capacity Manual (HCM) roundabout capacity equation was calibrated using these gap acceptance parameters. The proposed model yielded higher entry capacity (1,672 PCU/h) compared to the HCM model. Validation against actual field entry capacity values demonstrated a strong correlation ($R^2$ = 0.94), affirming the model's accuracy. Comparisons with international models, such as HCM 2016, Brilon-Wu, and Brilon-Bondzio, revealed the superiority of the proposed model in terms of entry capacity (1,672 PCU/h versus 1,380 PCU/h, 1,241 PCU/h and, 1,218 PCU/h respectively).

**Keywords**

roundabout, HCM, gap acceptance, critical gap, follow-up headways

## 1 Introduction

Roundabout is a type of intersection of a standard circular shape where the traffic is allowed to circulate around the central island. Typically, the circulating vehicles have priority, and all entering vehicles must decide whether to accept or refuse the gaps while awaiting to enter (Polus et al., 2003). In the 1970s, priority rules were the opposite in Hungary, and as a result, roundabouts were not safe. Thus, roundabouts were considered "dreaded intersections", so they were converted into traffic light intersections one after another (Mándoki and Soltész, 2018). The first modern roundabout was built in 1991, at the intersection of main road No. 53 and 55, and several others followed. In 1996, when there were already 23 roundabouts in operation on the Hungarian national roads, the Ministry of Transport, Communications and Water published the first edition of the road technical regulations entitled Designing Roundabouts (ÚT 2-1.206), decisively considering the French and partly the German experience. The technical regulation primarily served to increase the popularity and spread of roundabouts in Hungary (Hóz and Tóthné Temesi, 2010).

Since roundabouts are one of the main elements of traffic network, there are huge concerns regarding the capacity, safety, and performance of such intersections. There are several benefits of roundabouts when compared to conventional crossroads or T-junctions:

1. safety benefits, fewer accidents occur and those that occur are less serious due to lower speed and less conflict points (Al Hasanat et al., 2024; Datondji et al., 2016; Mándoki and Soltész, 2018);
2. the enhanced capacity of a roundabout intersection can lead to environmental benefits by potentially reducing the requirement for extra lanes to handle traffic demands, as compared to a signalized intersection (Brilon and Vandehey, 1998);
3. additionally, maintenance and operation costs are low as compared to other types of intersections (Brilon and Vandehey, 1998).

The capacity of roundabouts in Hungary is shaped by both driver behavior and technological developments

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in traffic management. Human factors such as critical gap and follow-up headway, which reflect drivers' decisions on when to merge into circulating traffic, are crucial. Advanced data collection and modeling techniques have improved the accuracy of these measurements, enabling better predictions of roundabout performance. This localized approach to understanding driver behavior and applying it to capacity models, like those in the Highway Capacity Manual, ensures that roundabouts in Hungary are designed for optimal efficiency and safety (Alharasees, 2024). Moreover, asphalt pavement must be able to endure various loads throughout its service life to maintain optimal effectiveness for flexible pavements. It is particularly susceptible to different forms of distress, especially under low and heavy traffic conditions at elevated temperatures (Alı et al., 2023).

On the other hand, traffic volume increases the cost of road infrastructure overall, lowers user comfort and safety, boosts maintenance and replacement expenses, and speeds up pavement degradation (Alothman et al., 2022).

## 2 Literature review

Several traffic authorities have developed design guidelines specifically for roundabouts such as the Highway Capacity Manual (HCM) 2016 (Transportation Research Board, 2016) and the UK empirical model (Kimber, 1989). Various capacity models are used for analyzing roundabout capacity and performance worldwide, categorized according to experimental and analytical methods (Kimber, 1980; Troutbeck, 1989):

1. experimental models rely on the correlation between geometric factors and actual capacity (Kimber, 1980),
2. gap acceptance model is based on driver's behavior (Transportation Research Board, 2016) and
3. microscopic model is based on the interaction between vehicles.

Vehicle movements resulting from gap acceptance, lane changing, car following, and other models are typically calculated individually for each vehicle at specific time steps (Tollazzi, 2015). The capacity of roundabouts is an important factor affecting their level of service (LOS), which is determined by queue lengths and delays. Various models, such as the interweave theory, regression models, and gap acceptance theory, have been developed to estimate roundabout entry capacity. Gap acceptance model is mainly based on two main parameters of the driver's behavior:

1. critical gap ($t_c$) and
2. follow-up headway ($t_f$).

The critical gap ($t_c$) is defined as the shortest time interval that an entering vehicle will accept to merge into the main traffic flow (Al Hasanat and Juhasz, 2022). Follow-up headway ($t_f$) denotes the interval required for two vehicles in a queue to enter a common gap within the main traffic flow (Yap et al., 2013). Troutbeck (2014) defines the critical gap as the minimum gap that a driver is presumed to accept. Since it is complicated to estimate critical gap on site, there are different methods to estimate the critical gap value in the literature such Raff's method, Wu's Model, Maximum likelihood method, Logit method, Siegloch method (Ashworth, 1970; Brilon et al., 1999; Raff, 1950; Tian et al., 1999; Troutbeck, 2016; Wu, 2012).

Several studies offer insights into critical gap estimations across different countries and methodologies. Fortuijn (2009) conducted research in the Netherlands using an unspecified estimation method, reporting a critical gap mean ranging from 3.16 to 3.28 seconds. Wu (1997) investigated in Germany, though the estimation method remains unspecified, with a critical gap mean recorded at 4.12 seconds, and no maximum value provided. Mahesh et al. (2016) conducted their study in India, employing the Raff's method, with a reported critical gap mean of 2.2 seconds, but no maximum value specified. Tolazzi (2004) conducted research in Slovenia without detailing the estimation method, reporting a critical gap mean of 4.8 seconds, without a maximum value specified. Romana and Núñez (2011) explored this topic in Spain without specifying the estimation method applied, with the reported critical gap mean ranging from 3.3 to 3.5 seconds. Finally, Greibe and la Cour Lund (2010) conducted a study in Denmark with an unspecified estimation method, reporting a critical gap mean ranging from 4.7 to 5.1 seconds. These diverse studies contribute to understanding critical gap estimations worldwide, showcasing variations in methods and reported values as shown in Fig. 1.

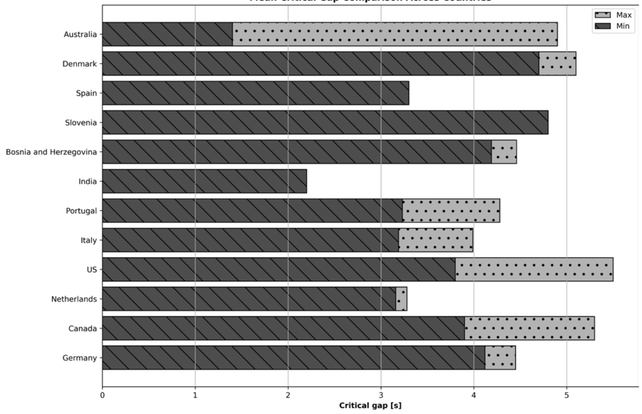


**Fig. 1** Mean critical gap comparison across countries

Table 1 provides a summary of studies conducted by researchers from various countries, focusing on the capacity of roundabouts. Each entry includes the author(s) and year of the study, the purpose and objectives, methodology employed, identified research gap, and any limitations acknowledged by the researchers.

**Table 1** Entry capacity research summary

| Author and year | Purpose and objectives | Methodology | Research gap | Limitation |
|---|---|---|---|---|
| Ali and Majad (2023) | The research sought to evaluate diverse theoretical frameworks regarding the traffic of roundabouts' capacity, for both multi-lane and single lane variants. | The researchers used gap acceptance, empirical, and simulation software methods. They also compared seventeen methods using virtual data. | The study contributes to the understanding of roundabout capacities and provides a comparison of various capacity prediction models | The investigation recognizes that accurately estimating capacity values relies on factors such as the traffic flow of vehicles within the roundabout, the flow of vehicles exiting it, driver conduct, and variations in its geometry. |
| Whitley et al. (2023) | The study attempted to gather headway information and fine-tune the roundabout capacity function outlined in the Highway Capacity Manual (HCM) using Lidar data collected from roadsides. | The authors introduced an automated technique for extracting headway data from roundabouts using Lidar data collected from roadsides. They illustrated how this headway data could be utilized to calibrate the roundabout capacity function outlined in the Highway Capacity Manual (HCM). | This research enhances comprehension of roundabout capacities and introduces a novel approach for extracting data and calibrating capacity functions, thereby enriching the field with valuable insights and methodologies. | The research acknowledges that accurately predicting capacity values hinges on a multitude of factors, including circulating flow, driver behaviors, variations in geometric design, and exiting traffic flow. |
| Al Hasanat and Janos (2023) | The study's objective was to devise a comprehensive capacity model tailored for roundabouts in Hungary, subsequently contrasting it with existing international models for comparative analysis. | The researchers utilized video recordings captured at five different roundabouts in Hungary to gather data on entering and circulating traffic. These datasets were then employed to construct individual models for each entry point and subsequently for each roundabout independently. | The study contributes to the understanding of roundabout capacities and provides a new empirical capacity model specifically for Hungary | The investigation recognizes that accurately forecasting capacity values is contingent upon multiple factors, including variations in geometric configurations, exiting traffic flow, circulating flow, and driver conduct. |
| Čudina Ivančev et al. (2023) | The research aimed to assess and contrast the saturation level estimations derived from both analytical and regression models specifically for single-lane roundabout entries. | The researchers designed 60 single-lane roundabout configurations with four legs, varying in dimensions and alignment. Subsequently, they calculated the level of saturation for roundabout entries using assumed traffic flows. | The study contributes to the understanding of roundabout capacities and provides a comparison of various capacity prediction models | The study recognizes that the outcomes are significantly impacted by the angle between the legs and the outer radius. |
| Chong et al. (2023) | The research aimed to investigate how drivers' utilization of lanes affects roundabout capacity at large multi-lane roundabouts during both peak and off-peak hours. | The researchers used video and voice recording techniques to gather traffic data at a 128 m inscribed diameter roundabout. They analyzed the turning entry flows to determine the lane utilization for left, through right, and U-turn movements | The study contributes to the understanding of roundabout capacities and provides insights into drivers' behavior at large multi-lane roundabouts | The study acknowledges that the results indicated some differences in the roundabout capacities for both scenarios, with the dominant lane differing from approach to approach as a result of lane utilization |
| Macioszek (2020) | The study aimed to determine the entry capacity of roundabouts, using those located in Tokyo, Japan, and their surrounding areas as a case study. | The researcher utilized data collected from single-lane roundabouts in Tokyo and their environs in 2019 for calibration purposes. | This research enhances our comprehension of roundabout capacities and introduces a novel method for calculating entry capacities tailored to the specific conditions observed in Poland. | The study acknowledges that the outcomes are significantly influenced by the geometric features and traffic characteristics of the analyzed roundabout. |

**Table 1** Entry capacity research summary (continued)

| Author and year | Purpose and objectives | Methodology | Research gap | Limitation |
|---|---|---|---|---|
| Patnaik et al. (2021) | The study aimed to devise two models for estimating entry capacities at signalized roundabouts, specifically tailored to heterogeneous traffic conditions. | The researchers employed two diverse methodologies for their examination: firstly, a multiple non-linear regression approach (MNLR) relying on regression techniques, and secondly, an artificial intelligence-driven model known as age-layered population structure genetic programming (ALPS GP). | This study advances our comprehension of roundabout capacities by introducing novel models tailored for signalized roundabouts operating under heterogeneous traffic conditions. | The investigation acknowledges that the weaving length emerges as the principal factor, making up roughly 27.72% of the MNLR-derived model used to estimate capacities for signalized roundabout entries. |
| Almukdad et al. (2021) | The study was set out to examine drivers' behavior and assess the capacity of two single-lane roundabouts by considering entry headway gap, circulating headway gap, and critical gap. | The research team gathered video recordings from two roundabouts located in Qatar. They integrated an extensive array of geometric predictors alongside information concerning circulating and exiting flows into their analysis. | This study enriches our understanding of roundabout capacities by introducing a novel method for quantifying entry capacity based on drivers' behavior at roundabouts. | The study acknowledges that accurately predicting capacity values relies on several factors, including driver behavior, variations in geometric configurations, circulating flow, and exiting traffic flow. |
| Pratelli and Brocchini (2022) | The study aimed to assess the capacity of Two-Geometry Roundabouts, categorized as unconventional roundabouts. | The researchers designed and analyzed Two-Geometry Roundabouts based on established design principles. They utilized the Highway Capacity Manual (HCM6th) to estimate the capacity of conventional roundabouts. | The study contributes to the understanding of roundabout capacities and provides a new method for estimating the capacity of unconventional roundabouts. | The study acknowledges that the results are highly influenced by the outer radius and angle between the legs. |
| Baby Zacharia et al. (2020) | The study aimed to investigate how priority violations affect the entry capacity of roundabouts. | The researchers employed the gap acceptance theory, a commonly utilized method for analyzing the capacity of roundabouts. | The study contributes to the understanding of roundabout capacities and provides insights into the impact of priority violations on entry capacity. | The research recognizes that priority violations, such as priority reversal and limited priority, frequently occur in diverse traffic situations. These violations can undermine the efficacy of gap acceptance models. |
| Ahmad and Rastogi (2019) | The study aimed to fine-tune the Highway Capacity Manual (HCM) model for assessing roundabout entry capacity under varied traffic conditions in India. | Researchers gathered data from five Indian roundabouts, determining Passenger Car Units (PCUs) based on lagging headway and width. They calculated critical gap values for vehicles by reducing the total sum of absolute differences in gap between the highest accepted and rejected gaps. | The study contributes to the understanding of roundabout capacities and provides a calibrated HCM model for heterogeneous traffic conditions | The study acknowledges that critical gap values in diverse traffic conditions are significantly lower compared to those documented in the literature for uniform traffic situations. It proposes calculating a multiplicative adjustment factor for different roundabout sizes to ensure that the adjusted Highway Capacity Manual (HCM) equation accurately represents traffic conditions in India. |

## 3 Methodology

In this paper thirteen roundabouts in Hungary in urban and rural settings were examined. A recording camera was used for data collection. The recording camera was placed on a 4-meter-high pole to assure a proper visibility of all entries of the roundabouts Fig. 2. An example of the recorded video is shown in Fig. 3.

The critical gap and follow-up headway for each entry was estimated by having enough data. All estimated critical gap values were calculated using Raff's method, the intersection point between rejected cumulative probability $1 - F_r(t)$ and accepted cumulative probability $F_a(t)$ is the critical gap based on Raff's definition (see Fig. 4) (Al Hasanat and Juhasz, 2022; Raff, 1950).

In this study, follow-up times for passenger cars were measured, given the lack of instances where heavy vehicles followed the same type of vehicle. Several readings were extracted from recorded videos for each entry, and the average value of the extracted follow-up times was calculated, thereby considering it as the follow-up time for this study.


**Fig. 2** Camera setup at one of the selected roundabouts


**Fig. 3** An example of the recorded videos of one of the roundabouts

A total of 41 entries are included in this paper. Both values of critical gap and follow-up headway for each roundabout's entry were employed to calibrate the HCM 2016 model. The interference caused by pedestrians and cyclist were neglected in this study. The recorded videos of the selected roundabouts were the main source of data of the traffic operation.

Fig. 5 illustrate the quantity of observations used in estimating the critical gap for each roundabout, alongside the inscribed diameter extracted from vector maps provided by the Hungarian road authority or by using Google Maps.

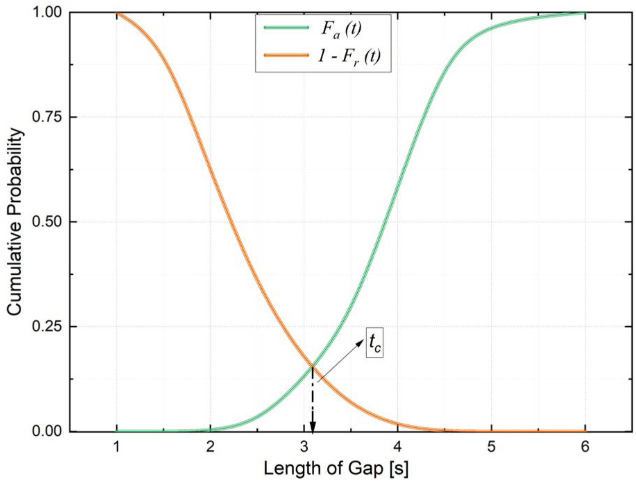


**Fig. 4** Critical gap estimation using Raff's graphical method

HCM capacity model considered to be one of the commonly used models for roundabouts in the literature. The assumed values of critical gap and follow-up headway in HCM 2016 capacity for single-lane roundabouts were 5 and 2.6 seconds respectively. These values are lower than the values presented in the HCM 2010 which were 5.19 and 3.19 seconds respectively (Transportation Research Board, 2010). The equation developed in HCM 2016 is expressed in Eq. (1)

$$C_e = Ae^{-Bv_c} \quad (1)$$

Where $v_c$ is the circulating traffic flow in passenger car unit per hour, $A$ and $B$ are the parameters determined based on the gap acceptance parameters are expressed in Eqs. (2) and (3):

$$A = 3600/t_f \quad (2)$$

$$B = \left(t_c - t_f/2\right)/3600 \quad (3)$$

In which $t_c$ is the critical gap and $t_f$ is the follow-up time in seconds.

## 4 HCM capacity

The parameters used in the HCM 2016 model are summarized in Table 2.

The descriptive statistics of the inscribed diameter, critical gaps, and follow-up times of the selected roundabouts are shown in Table 3.

## 5 Analysis and results

Since all the gap acceptance parameters are known for all forty-one entries, the calibration of the HCM 2016 model Eqs. (1)–(3) for each roundabout's entry is generated.

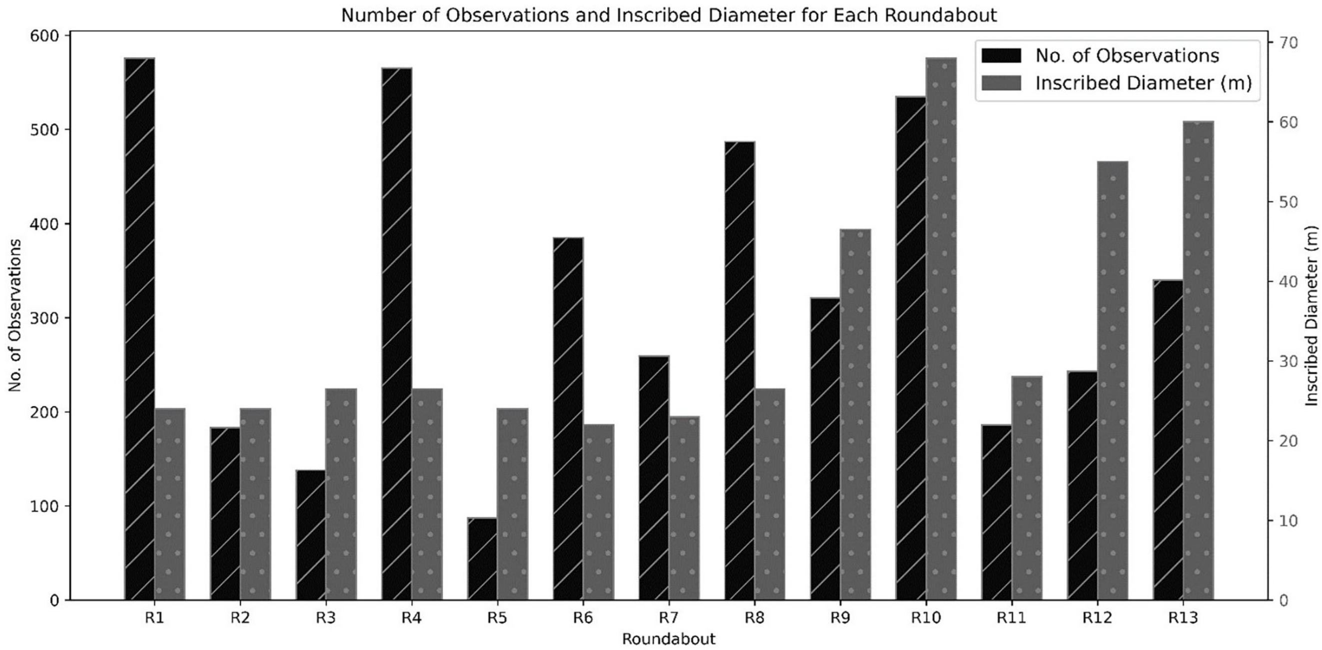


**Fig. 5** Number of observations and inscribed diameter for each roundabout

**Table 2** Parameters characteristic of the HCM 2016 capacity model equation

| | $A$ | $B$ | $t_c$ (s) | $t_f$ (s) |
|---|---|---|---|---|
| Single lane opposing single circulating lane | 1380 | $1.02 \times 10^{-3}$ | 5 | 2.6 |
| Two-lane entries opposing one circulating lane | 1420 | $0.91 \times 10^{-3}$ | 4.5 | 2.53 |
| Two-lane entries opposing two circulating lanes | 1420 | $0.85 \times 10^{-3}$ | 4.4 | 2.53 |
| Two-lane entries opposing two circulating lanes (right) | 1420 | $0.85 \times 10^{-3}$ | 4.4 | 2.53 |
| Two-lane entries opposing two circulating lanes (left) | 1350 | $0.92 \times 10^{-3}$ | 4.7 | 2.7 |

**Table 3** Descriptive statistics of the selected roundabouts

| | Inscribed diameter | Critical gap | Follow-up time |
|---|---|---|---|
| Count | 13 | 41 | 41 |
| Mean | 34.923077 | 3.04122 | 2.118261 |
| Std | 16.299088 | 0.229926 | 0.188035 |
| Min | 22 | 2.41 | 1.8282 |
| 25% | 24 | 2.91 | 1.94361 |
| 50% | 26.5 | 3.09 | 2.1 |
| 75% | 46.5 | 3.2 | 2.31604 |
| max | 68 | 3.46 | 2.39629 |

The graphical representation of the calibrated HCM model for all thirteen roundabouts is as illustrated in Fig. 6 (Al Hasanat and Juhász, 2023; Al Hasanat and Schuchmann, 2022a; 2022b). The increase in the roundabout's inscribed diameter has been observed to correspond with an increase in the overall capacity of single-lane roundabouts in which it positively impacted the performance of single-lane roundabouts. This observation aligns with the conclusions of (Al Hasanat and Janos, 2023), which used the empirical method to determine roundabout capacity instead of the gap acceptance theory.

Nonlinear regression was performed on the available data to derive a comprehensive model from all the individual models obtained through the gap acceptance approach; see Fig. 7.

Table 4 represents the results of a nonlinear regression analysis performed to estimate the capacity model of roundabouts. It outlines the coefficients ($A$ and $B$) alongside their respective numerical values, standard errors, $t$-values, probabilities, and dependency coefficients. These coefficients are pivotal in formulating estimations for roundabout capacity, quantified in terms of Passenger Car Units per hour (PCU/h).

The capacity model was developed via non-linear fitting, resulting in an $R^2$ value of around 0.86, implying a robust relationship between the dependent and independent variables. Moreover, the model exhibits to be statistically significant. Eq. (4) presents the mathematical expression of the obtained capacity model.

$$C_e = 1672 e^{-0.000643 \times v_c} \quad (4)$$

The statistical parameters resulting from the nonlinear regression analysis conducted to formulate the capacity model for roundabouts are summarized in Table 5.

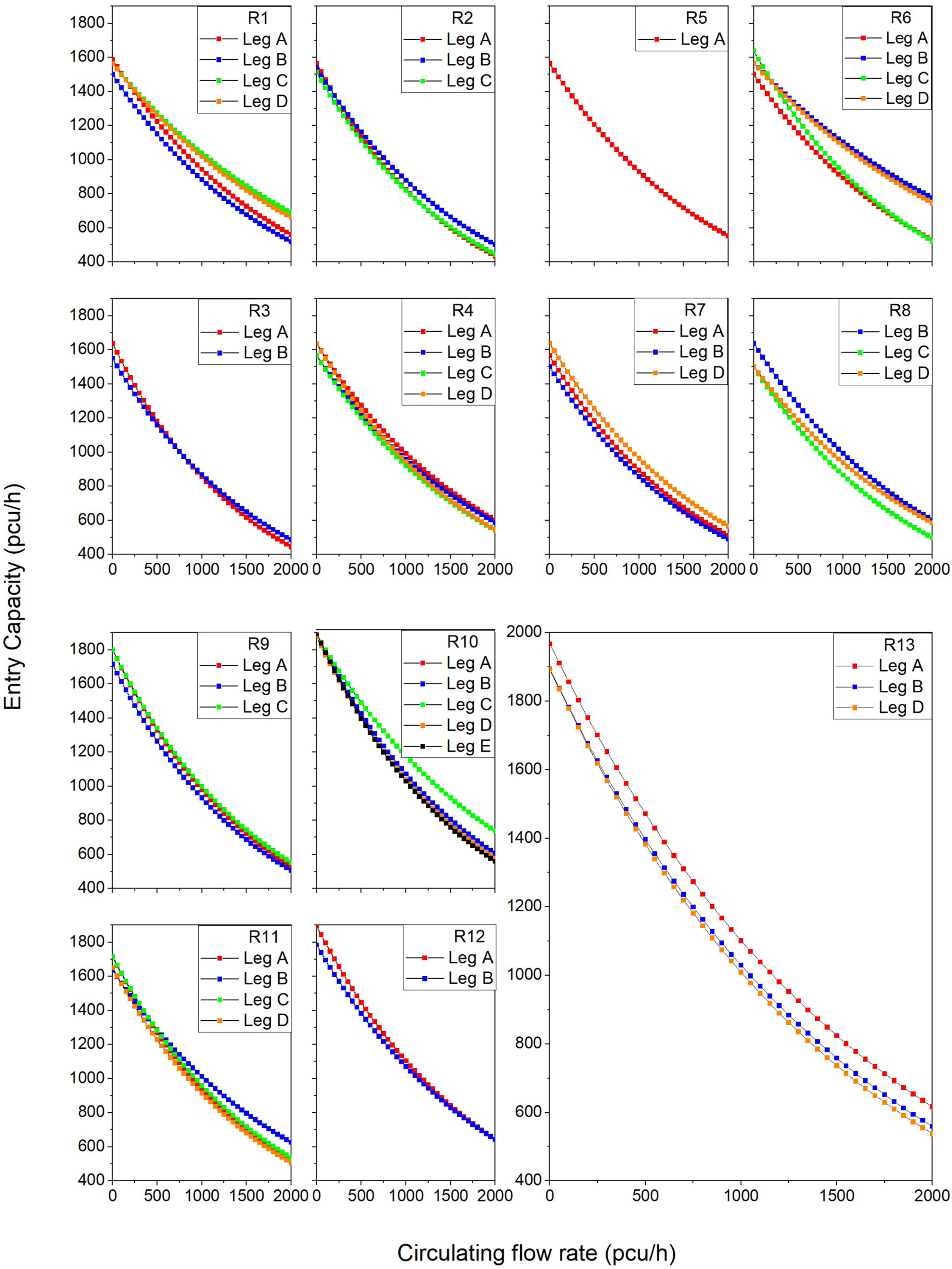


**Fig. 6** The graphical representation of the calibrated HCM model for all thirteen roundabouts

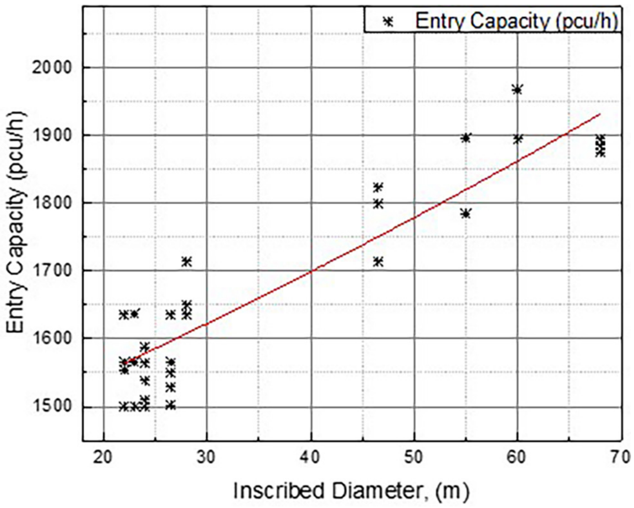


**Fig. 7** Entry capacity vs. different inscribed diameter sizes

**Table 4** Parameters estimated by nonlinear model

| | | Value | Standard error | $t$-value | Prob > $\|t\|$ | Dependency |
|---|---|---|---|---|---|---|
| Capacity (PCU/h) | $A$ | 1672.51744 | 8.29492 | 201.63 | 0 | 0.59096 |
| | $B$ | $-6.42 \times 10^{-4}$ | $6.4 \times 10^{-6}$ | −84.73 | 0 | 0.59096 |

**Table 5** Statistical characteristics of general model

| | Capacity (PCU/h) |
|---|---|
| Number of points | 760 |
| Degrees of freedom | 758 |
| Reduced $\chi^2$ | 9555.06959 |
| Residual sum of residual | 7242742.74598 |
| $R^2$ | 0.91275 |

The study determined the adjustment factor ($f_a$) by comparing the results of nonlinear analysis with those from the adjusted HCM model. Table 6 shows the calibrated HCM model alongside the corresponding adjustment factors for various inscribed diameters of single-lane roundabouts.

## 6 Model validation

For a comprehensive evaluation of the effectiveness of the proposed model, it was necessary to select and extract data from another roundabout. Consequently, additional entry capacity data was gathered from another roundabout located in Budapest. This particular roundabout features a central inscribed diameter of 55 meters.

The actual entry capacity values observed in the field for this roundabout were compared with the predictions made by the proposed model. These findings were illustrated in Fig. 8. Upon analyzing the graph, a robust correlation was noted amongst the field-derived values and the estimations provided by the proposed model, demonstrating a substantial coefficient of determination ($R^2$) of 0.94.

Furthermore, it was noted that the field capacity values only deviated by a mere ±4% from the proposed model's estimates.

## 7 Model comparison

Following the finalization of the proposed model's structure, the proposed capacity model was utilized as a benchmark for comparing against other models in this study. Fig. 9 illustrates a comparative analysis between the proposed capacity model and other models such as the HCM 2016, Brilon-Wu, and Brilon-Bondzio.

The proposed capacity model demonstrates a maximum entry capacity of 1,672 PCU/h, surpassing the capacity of the HCM model, which stands at 1,380 PCU/h. In contrast,

**Table 6** Adjustment factors for roundabouts of different sizes

| Roundabout ID | Inscribed diameter, (m) | Adjustment factor, $f_a$ | Parameters | | Entry capacity $C_e$ |
|---|---|---|---|---|---|
| | | | $A$ | $B$ | |
| R1 | 24 | 1.075933 | 1554 | 0.000473 | $C_e = f_a A e^{-Bv_c}$ |
| R2 | 24 | 1.087126 | 1538 | 0.000603 | |
| R3 | 26.5 | 1.049592 | 1593 | 0.000615 | |
| R4 | 26.5 | 1.045 | 1600 | 0.000518 | |
| R5 | 24 | 1.069738 | 1563 | 0.000453 | |
| R6 | 22 | 1.067007 | 1567 | 0.00055 | |
| R7 | 23 | 1.075241 | 1555 | 0.000507 | |
| R8 | 26.5 | 0.939854 | 1779 | 0.000603 | |
| R9 | 46.5 | 0.885124 | 1889 | 0.000571 | |
| R10 | 68 | 0.996424 | 1678 | 0.000563 | |
| R11 | 28 | 0.90919 | 1839 | 0.000525 | |
| R12 | 55 | 0.871287 | 1919 | 0.000607 | |
| R13 | 60 | 1.075933 | 1554 | 0.000473 | |

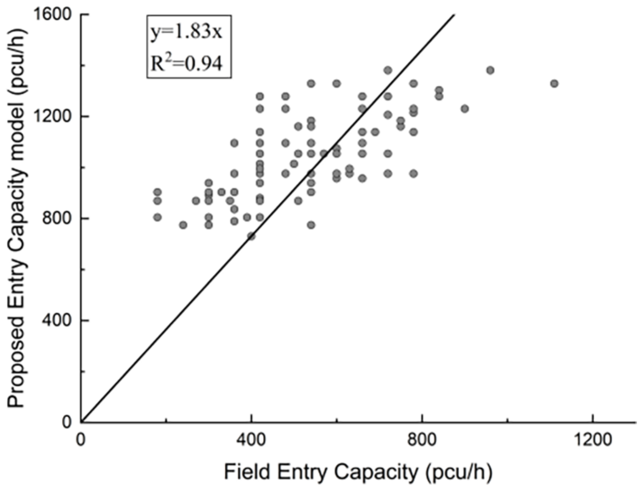


**Fig. 8** Comparison between field and proposed model

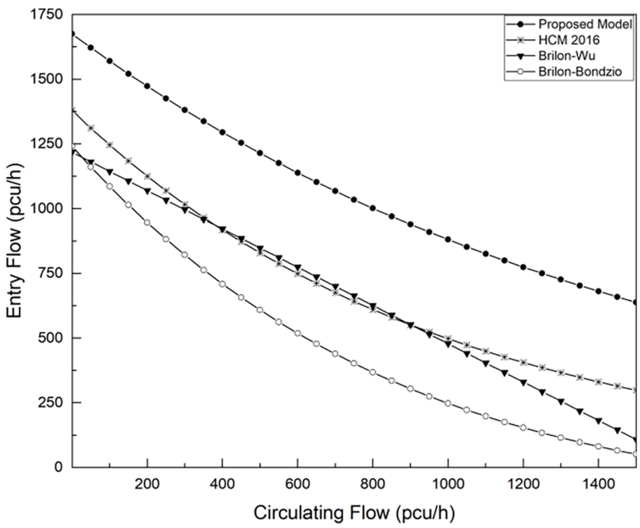


**Fig. 9** Comparison of international capacity models to the proposed model

the entry capacities of the Brilon-Wu and Brilon-Bondzio models are notably lower, at 1,241 PCU/h and 1,218 PCU/h, respectively, compared to the proposed capacity model.

## 8 Conclusion

Data were collected form thirteen single-lane roundabouts in Hungary using recorded videos and the selection of roundabouts was also based on different inscribed diameters sizes.

Since the aim of this study was calibrating the HCM model for Hungary, the critical gap and follow-up headway for each roundabout entry were estimated, the critical gap value was estimated using Raff's method and follow-up time estimated by taking the average of 8 occasions. It has been found that the critical gap values for all entries are lower than the values of HCM 2016.

The entry capacity of each entry of the selected roundabouts were found to be vary from one entry to another, those variations of entry capacities are illustrated in Fig. 6.

All the roundabouts' entries show a higher capacity than the equation presented in HCM 2016, with a percentage difference between the HCM model and the proposed model that is higher by +19.135%, and adjustment factors for different inscribed diameter of roundabouts were also found.

Moreover, a statistical analysis employing non-linear fitting was conducted to determine the proposed model estimating the entry capacity of single-lane roundabouts, resulting in an $R^2$ value of approximately 0.86.

After conducting model validation, a roundabout in Budapest area with an inscribed diameter of 55 m was selected for this purpose. It has been found that a strong relationship existed between the field-derived values and proposed model estimation, with a significant coefficient of determination ($R^2$) of 0.94.

Therefore, model comparison of the proposed model with other models was performed. The proposed entry capacity model of this study is higher than that of the HCM model, Brilon-Wu, and Brilon-Bondzio with a percentage difference of 19.14%, 29.6%, and 31.4%, respectively.

The methodology employed in this study is transferrable and applicable to other regions with similar driving cultures. However, further research is warranted. Exploring additional roundabout geometries could enhance understanding, and expanding the number of roundabouts for model calibration and validation would strengthen its robustness.

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