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Research Paper

Developing a capacity model of normal roundabouts based on simultaneous geometric and traffic parameters using microscopic simulation

Roozbeh Ebrahimi Golshanabadi [1], Behrooz Shirgir [2,*]

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Abstract

One of the types of unsignalized intersections is roundabout, which usually has an advantage in terms of efficiency and safety in low to medium traffic conditions. In general, roundabouts are created as a solution to solve traffic problems at intersections, as well as to create ease and safety in weaving movements. As the volume of traffic increases and according to the dimensions and geometric design of the roundabout, its efficiency gradually decreases. Considering the issue of road traffic due to its globalization, it is necessary to develop a transportation network that can be efficient now and in the future. To this aim, proper design and analysis of various infrastructures are performed. One of these infrastructures created in the road network to increase the efficiency of intersections by reducing delay is roundabout. At present, a strong model for Iran's traffic conditions is not available to determine the performance of roundabouts; Therefore, in this research, an attempt has been made to prepare a model to determine the performance of roundabouts based on geometric characteristics. Among the available global models, it has been observed that the geometric characteristics of roundabouts play an important role in roundabout capacity. Therefore, concerning this issue as a basis, a model for roundabout entry capacity has been produced for heterogeneous traffic conditions in Iran. According to the research results, the entry capacity model, which is described by the variables 1- circulating flow, 2- central island diameter, and weaving width, is the best in terms of statistics has been the best model statistically. It was observed that with each meter increase in the diameter of the central island, the entry capacity of the roundabout increased by 6%. Also, with each meter of weaving width, the entry capacity has increased by 35%.

Keywords: Modern Roundabouts, Unsignalized Intersections, Roundabout Capacity, Geometric Characteristics

[*] Corresponding author. E-mail: shirgir@khu.ac.ir

[1] M. Sc. Graduated, Department of civil Engineering, Kharazmi University, Tehran, Iran.

[2] Assistant Professor, Department of civil Engineering, Kharazmi University, Tehran, Iran.

1. Introduction

Transportation and traffic are among the main and infrastructural activities of an urban complex that are very important in shaping the structure of a city. The basic and constituent elements of a city, which are the streets, intersections, and urban spaces, are the basic foundations of the transportation system. Due to this special role and importance, it needs to be carefully studied and various methods are proposed for optimal design and control. Unsignalized intersections have many collision points, which is their main weakness. As the number of entry lanes increases, the anomalous flows at the intersection also increase significantly. Over the years, many reforms have been made to reduce this. A roundabout is an intersection or junction where traffic flows almost continuously in one direction around a central island. Nowadays, traffic jams at intersections are commonly seen in Iran during peak morning and afternoon hours. Therefore, the police must intervene in the situation and regulate the traffic flow by overshadowing the traffic control devices. Otherwise, it is impossible to have a normal traffic flow, especially in areas that are more dependent on driving behavior and the balance of traffic flow between approaches. This problem will continue and may even worsen in the future due to rapid population growth and the number of vehicles in Iran. Poor road planning and non-standard geometric design of roundabouts have a great effect on the capacity of roundabouts and traffic congestion. Therefore, it is vital that the capacity of roundabouts for proper traffic performance be assessed and that a clear picture be given to urban planners and traffic engineers who are responsible for designing intersections and controlling traffic.

2. Literature Review

The main goal of traffic designs is to have a safe and efficient flow. A Measure of Effectiveness has been proposed for each component of the transport facility. For example, Highway Capacity Manual has introduced the average control delay as a measure of effectiveness. Due to the widespread use of roundabouts worldwide, issues such as capacity, delay, etc have not yet been studied in detail. The performance of traffic in roundabouts is examined in two ways (Rodegerdts, et al., 2010):

- Facility capacity
- The level of performance is often measured in terms of one or more criteria such as delay and queue length.

Drivers entering a roundabout must slow down to coordinate safely with other users. The entry width, the entry flare, and the volume of traffic at the entry control this speed. If some of the roundabout entries are wide or have a short auxiliary lane, they provide more capacity, because the wider entries require a larger roundabout and thus more opportunities for… . They provide traffic to move in groups, and thus the number of acceptable opportunities for entry increases, followed by increased capacity (Murphy, 2015).

As theories are debated, there is usually a growing desire to experiment with them. In some cases, there is a desire to test a particular model. In others, there is a tendency to evaluate a parameter. In other contexts, there is a tendency to examine situations that have not yet been theoretically explored. Sometimes experiments are needed to gain sufficient knowledge of a system to begin modeling. There are many problems with conducting traffic tests on operational facilities. The tester must find a suitable location, prepare a suitable instrument, and then wait for the appropriate traffic conditions to arise. If these conditions last only a short time, the tests may be performed in a few days or weeks. As a result, it may not be possible to repeat a problem in this area. Some traffic conditions may not occur at all in an operational facility. Some tests may indicate a dangerous condition. Some experiments may require the construction of expensive facilities. Experimental routes, such as those available at the Transport and Road Research Laboratory in Crowthrone, UK, perform a range of tests that do not require complex construction or create hazardous conditions. However, even performing these tests on a test track can be very expensive and requires the provision of vehicles, drivers, etc (Shaaban & Hamad, 2020).

2.1. The Concept Of Roundabout Capacity

The capacity of each entry for a roundabout is the maximum vehicle rate that can be reasonably expected to enter the roundabout from an entry over a period of time, under the prevailing traffic and geometric conditions of the road. A performance analysis considers a specific set of geometric conditions and traffic flow rates that typically performs a 15-minute analysis period for each roundabout entry. Traffic volume data for an urban roundabout should be available at least in the morning and evening peaks. The maximum flow rate that can be expected at a roundabout entry depends on two factors (Ahmed, et al., 2020):

- Circulating flow that conflicts with the entry flow
- Geometric components of the roundabout

When the flow rate is low, drivers at the entry can enter the roundabout without significant delay. Larger intervals in circulating flow are more beneficial for oncoming drivers, as more than one vehicle may enter. As the flow rate increases, the amount of time interval in the flow decreases, resulting in a decrease in the rate of incoming vehicles. Geometric components of the roundabout also affect the entry flow rate. The most important geometric factor is the entry and circulating widths. The two entry lanes double the rate of entry flow compared to one entry lane, and a wider roundabout allows vehicles to move side by side. Roundabouts are designed for a capacity performance of less than 85%, as above 85%, delays and queues increase significantly above average.

2.2. Capacity Models

Roundabout capacity is the main parameter for measuring the roundabout performance criterion among other parameters such as delay and queue length. Capacity models are of two types: 1) Analytical models that are based on the gap acceptance theories and do not require real and direct observations. 2) Experimental regression models based on traffic flow and geometric parameters. Kimber states that capacity estimation based on analytical models to be implemented in the UK is not appropriate due to the different behavior of drivers. Fisk, on the other hand, finds regression models inefficient and difficult due to the need for large amounts of data (Fisk, 2002).

2.2.1. Microscopic Simulation Models

Two types of tools are used when analyzing the roundabout capacity. The first type is based on the computational model used in RODEL and aaSIDRA, while the other type is micro-simulation based on Vissim and SimTraffic. Bard has concluded in his studies that the roundabout capacity obtained from Vissim is less than the capacity of aaSIDRA software. He clarified that this case also applies to both one-lane and two-lane roundabouts. Several scenarios have been built into Vissim, and many comparisons with NCHRP 572 data have been reviewed. Lee et al. Conducted a simulation experiment to examine the sensitivity analysis (Mauro, 2010). They presented a modified model for influencing factors and capacity coefficients. As a result, simulation-based models can provide more realistic scenarios of traffic performance in fields because performance characteristics can be accurately modeled and reflected.

2.3. The Nature of Simulation

Over the past 20 years, various definitions and interpretations of so-called simulation have been given. In general, its modern meaning refers to an experiment performed on an artificial model based on a real system. The main advantage of current simulations is the use of digital computers to implement a model. The main simulations performed for traffic flow are those performed using digital computers (Campbell & Townsend, 2020).

Reasons for the simulation include the following:

1) Need to test the behavior of the new system or operating procedure before actually building it:

a) Building a new system can be very expensive or time-consuming.

b) Experiments with the actual system may present a significant hazard (such as driving accidents).

2) The need to test alternating systems under the same conditions. (For example, it is never possible to replicate exactly one particular traffic situation in one place; it is very common in simulation to apply the same traffic condition to multiple systems.)

Vissim is made by PTV Group in Germany. This software uses the Wiedemann model to control vehicle behavior (BARTIN, 2017). Compared to other simulation software, most users use Vissim to model the roundabout. Trueblood proved that Vissim can simulate the behavior of drivers in a roundabout. Galli et al. analyzed the performance of a single-line field under three scenarios in Vissim (Galelli & Vaiana, 2008), but the simulation model was not calibrated with field data. Walds et al. used velocity data to calibrate a two-lane roundabout model in Vissim (Valdez, et al., 2011) and this model was used to obtain the mean control delay and level of service. Seiko et al. calibrated a roundabout model with two entry lanes and two circulating lanes in Vissim using predicted velocity (Cicu, et al., 2011). They developed a roundabout model with Vissim and calibrated it with three capacity-based strategies. Li calibrated a multi-lane roundabout model in Vissim using free-flow vehicle entry and gap acceptance data (Li, et al., 2013). Sensitivity analysis was performed to establish a quantitative relationship between Vissim parameters and the distances taken. Bard calibrated the roundabout model with critical gap data and developed a new formula for the two-lane roundabout.

In some studies, researchers used Vissim to evaluate the performance of non-standard roundabout designs. Lochrane et al. used Vissim to model and evaluate the capacity of small roundabouts (Lochrane, et al., 2014). Fortuijn used Vissim to model a turbo roundabout in the Netherlands, then the simulated capacity of the turbo roundabout was compared with normal roundabouts (Fortuijn, 2009). According to existing studies, three sets of parameters can be used to calibrate the roundabout model in Vissim. The first set of rules is about priority rights (PR) and conflict area (CA) that control gap acceptance behavior..

2.4. The Effect of Geometric Characteristics on the Roundabout Capacity

Modern roundabouts have undergone dramatic changes from the placement of a small post in the middle of the intersection to what it is today. Changes in roundabout configurations are geometrically inevitable, including the diameter of the perimeter circle and the width of the roundabout as traffic flows change over time (Kieća, et al., 2019).

A study in this case by Polus and Shmueli shows that the capacity model of the roundabouts depends on the diameter of the surrounding circle. This model shows the relationship between entry and circulating flow exponentially and analyzed flow and geometric data from six roundabouts in small to medium dimensions. The entry and circulating flow relationships were calibrated using descriptive circle diameters as descriptive variables. Circulation flow changes were used for modeling considering only the conflicting flow and not the complete circulating flow (Polus & Shmueli, 2011).

Al-Masaeid and Faddah found that the diameter of the central island, the width of the entry, the width of the roundabout had a great effect on the capacity of the roundabout. They developed a nonlinear regression model in power and logarithmic forms (Al-Madani & Saad, 2009). Al-Madani and Pratelli modeled the entry capacity using the circulating and output flows, the number of entry and circulating lanes, the entry and circulating width, and the length of the weaving section. The variables were considered separately or in combination with each other (Al-Masaeid & Faddah, 1997).

3. Methodology

To measure the impact of geometric variables on Iran's traffic conditions, a model was developed based solely on it, citing the importance of geometric variables. To study the variables affecting the capacity and evaluate the capacity model in lightless urban roundabouts, traffic volume information, and geometric design features in a number of unsignalized roundabouts are required. The information should be collected in such a way that in each time period (in this study of 15 minutes), enough observations of traffic volume for different movements in the roundabout be collected, and also the volume of traffic is collected separately for vehicles in the same time periods. As far as possible, the weather conditions should be the same for all roundabouts.

3.1. Site Selection and Sampling

Iran is a combination of different cultures, and people behave differently in different parts of the country. The development of construction, living environments, and transportation are also diverse in each sector. Therefore, it can be concluded that in summary, driving behavior and traffic composition, and transportation facilities are different in various parts of Iran. As a result, the main issue is the choice of roundabouts in the right places.

To study the capacity in unsignalized roundabouts, six roundabouts with different characteristics in the provinces of Tehran and Alborz were selected, and the required information was collected. These roundabouts were selected from about 38 roundabouts in Tehran and Alborz provinces, and it has been tried to make these roundabouts different in terms of the type of streets leading to them, and secondly these roundabouts should be selected from different areas of the city. After conducting the necessary studies, Bahonar, Tohid, and Golha roundabouts from Alborz province and Abuzar, Sarollah, and Mehrvarz roundabouts from Tehran province were selected for the census. It should be noted that the statistics of Tohid and Mehrvarz roundabouts have been used to validate the models.

As we know, there are many methods for counting traffic volumes, such as manual counting, using mechanical counters, and video recording, among which video recording is the most common. In the present study, the videography method has been used to count the volume of vehicles by type. One of the advantages of this method over the manual method is that the results are more accurate and accessible. The filming time in all roundabouts is 2 hours. The filming took place during the peak hours of the evening. Then, by watching the videos, the desired information was extracted from the videos. The number of vehicles is recorded separately for passengers, bus, truck, and motorcycle in specific time periods (in this 15-minute study).

4. Model Development

The more data that can be obtainde, the better the model development result will be achieved. Because the collected data includes geometric characteristics, entry flow, and circulating flow, it is an exponential variable to consider geometri c variables and circulating flow. Final model is expanded using the multiple regression method for entry capacity.

For traffic modeling in the baseline scenario, GEH less than 5 is an appropriate value between the modeled and observed hourly volume (streams with longer or shorter time intervals must be converted to hourly equivalent to use these thresholds). According to the DMRB, 85% of the traffic model volumes must have a GEH of less than 5. GEH in the range of 5 to 10 may hamper research. If the GEH is greater than 10, there is a high probability that there is a problem with the trip request or data model (this could be something of a data entry error, or it could be interpreted as a severe problem in model calibration). To simulate each of the roundabouts, one of the inputs was used to calculate the GEH values and the Golha roundabout calculations shown in Table (1).

Table 1. GEH values for Golha roundabout

	North to South	Direction of movement	North Kalhor	Street name	Golha	roundabout name
		Hour / actual - Simulation	simulation	actual		
GEH	%Difference	Difference(veh/hr)	Vehicle/600s	Vehicle/600s	total	time of study
0.72	3.4	90	426	441	661.5	19:00_19:15
0.38	1.88	48	417	425	636.25	19:15_19:30
0.53	2.53	66	423	434	650	19:30_19:45
0.48	2.33	60	418	428	640.75	19;45_20:00
0.34	1.67	42	412	419	627.5	20:00_20:15
0.57	2.75	72	423	435	651.5	20:15_20:30
0.38	1.88	48	417	425	636.25	20:30_20:45
0.81	3.81	102	429	446	668	20:45_21:00

5. Relationship Between Entry and Circulating Flow

Initially, flow data, including entry flow and circulating flow, are extracted from VISSIM simulation data at one-hour intervals. Then, the relationship between entry flow and circulation for each approach was considered. The linear relationship between the entry flow and the circulating flow shows that the maximum circulating flow is reached when the entry flow reaches zero, but this never really happens. The first step in developing a model was to determine the relationship between entry and circulating flow. The statistical tests presented in previous research show that the most useful theoretical distribution to describe the relationship between circulating flow and entry is the modified exponential distribution. This is because the correct result is given in all ranges of traffic flow volume values for all roundabouts (Macioszek, 2020).The relationship between the entry and circulating flow for the roundabout with the two circulating lanes of Golha is shown in Figure (1). This regression method is performed for all roundabout entries at the peak hour, and the results are shown in Figure (2).

As mentioned above, the modified exponential relationship in the model development process gives the best possible fit. The connection thus created between the entry flow and the circulating flow for an approach is generally expressed as follows:

$$q_e = A * e^{-Bq_c} \quad (1)$$

Where q_e and q_c are the entry and circulating flows, respectively, the square values of R regression equations for different entries vary from 0.87 to 0.97. The values of regression coefficients (A and B) for the various inputs intended for model development are shown in Table (2).

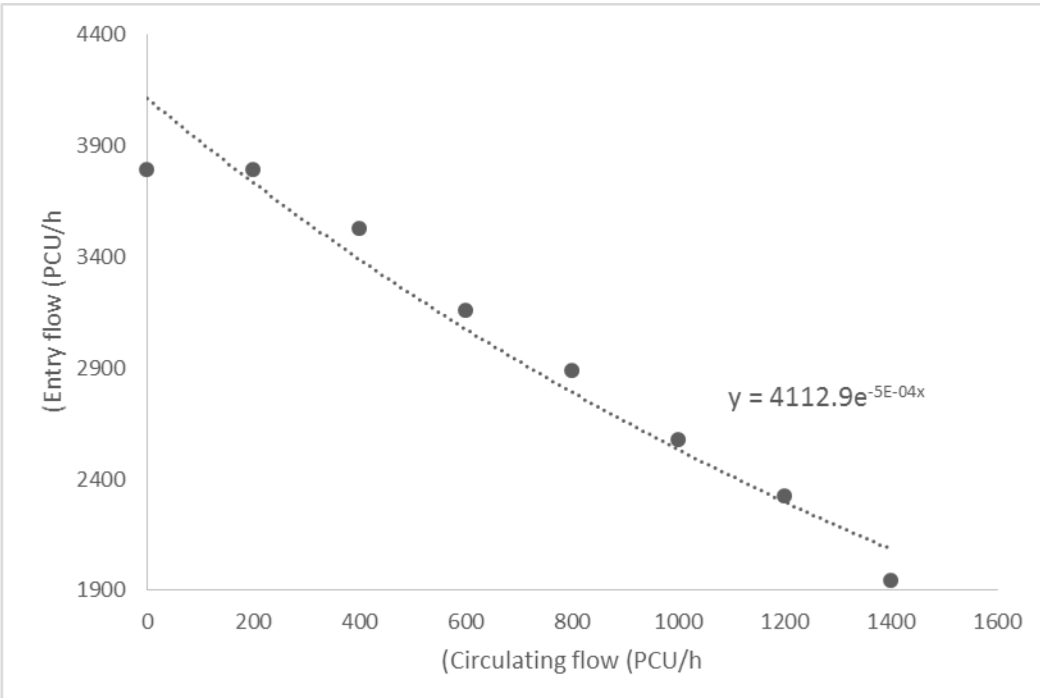

Figure 1. Relationship between entry and circulating flow for the north Kalhor entry of Golha Roundabout

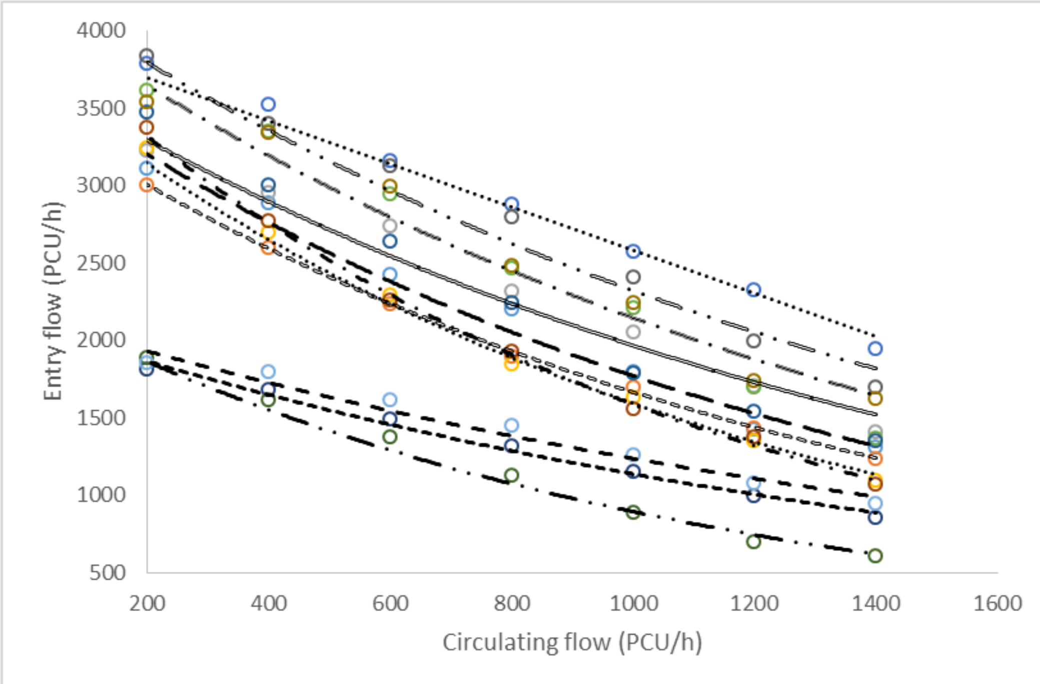

Figure 2. Relationship between entry and circulating flow for 13 different entrie

Table 2. Average entry flow and regression correlation coefficients for different entries

roundabout name	Approach	entry flow (PCU/h)	A	B	R^2
Sarollah	North Taleghani	1542	2430.4	0.0007	0.9674
	Varamini Blv	1430	2374.4	0.0008	0.9579
	Shokoofeh Blv	1595	2462.9	0.0007	0.9743
	South Taleghani	1713	2677	0.0007	0.9778
Aboozar	Ahmadi	836	1159	0.0005	0.8773
	West Aboozar	758	1263	0.0008	0.9342
	Ghorbani	846	1134	0.0005	0.9123
Golha	Kasra	3002	4112	0.0005	0.9621
	Bijan	2688	4266	0.0007	0.9576
Bahonar	Rajai Blv	1971	2893	0.0006	0.9416
	Zafar Blv	1862	2886.7	0.0007	0.9729
	West Bahonar Blv	1868	2687.3	0.0006	0.9295
	East Bahonar Blv	2147	2980.4	0.0005	0.8909

5.1. The Relationship Between the Entry Flow and the Various Geometric Elements

Geometric characteristics play a decisive role in determining roundabout capacity. Therefore, it is crucial to study the importance of changing the entry flow with a geometric characteristic. To determine this relationship, both the entry flow and the geometric elements must be linear. For this purpose, the logarithm of the entry flow values was calculated. This provides a linear relationship between the two variables and makes it easier to determine their relationship. Each geometric element's changes were determined separately by the logarithm value of the entry flow and were combined to develop a complete model based on geometric elements along with the circulating flow.

The diameter of the central island shows the logarithmic changes with the entry flow logarithm, as shown in Figure (3), while the weaving width shows a linear relationship. Weaving length and entry angle did not show a significant relationship and were therefore excluded from model development. Therefore, two geometric elements were used for the final model.

5.2. Model Development

The entry flow data relationship is obtained for 13 entries, as shown above. The regression parameters obtained by these lanes are used for further analysis. Regression with geometric variables and entry flow was performed as previously discussed to obtain entry capacity changes with each variable. Finally, according to the geometric variables and circulating flow, three equations were created using multiple regression analysis with three approaches. The first approach is without considering the geometric characteristics given in Equation (2), and its R^2 value is 0.704. The second approach is calculated by adding the diameter of the central island, which is given in Equation (3) with R^2 value equals 0.819. The third approach was obtained by considering both geometric features given in Equation (4), and the R^2 value was equal to 0.891. The parameters were significant even when they were all considered together.

The equations obtained for capacity by this method are as follows:

$$q_e = 1947e^{-0.001q_c} \tag{2}$$

$$q_e = 26.73D^{1.239}.e^{-0.001q_c} \tag{3}$$

$$q_e = 0.273D^{1.161}.e^{0.324WW}.e^{-0.001q_c} \tag{4}$$

q_e = Entry Capacity (PCU/h), D = Central Island Diameter (m), WW = Weaving Width (m)

q_c = Circulating Flow (PCU/h)

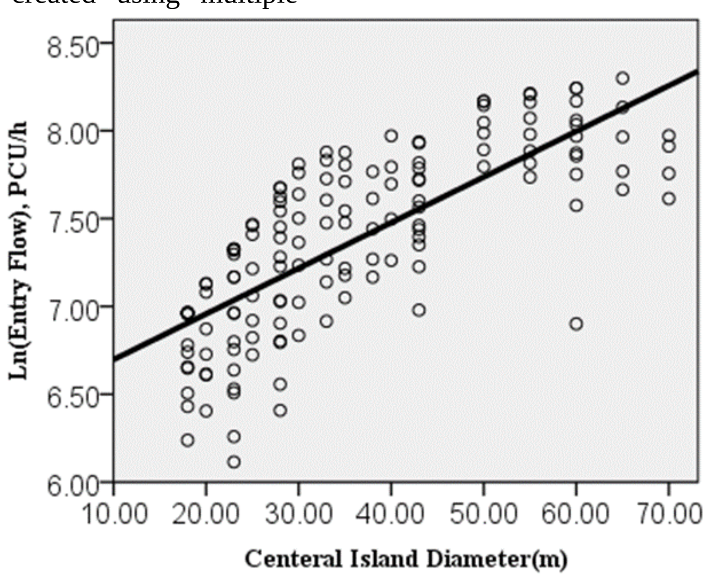

Figure 3. Relationship between entry flow and central island diameter

6. Comparison with International Models

Given the differences in the types of international models presented in terms of required input variables, the first step is to evaluate existing capacity models' ability to predict entry capacity in existing approaches. Using a comparison of existing models and collected data, the following can be identified in the first step:

Are international models applicable to the status quo? A prerequisite can be obtained to understand better capacity modeling based on the same data by comparing the types of models mentioned. Among the introduced models, Girabase model (France), HCM2000 model, and Bovy_Tan model (Switzerland) were not used in the comparison process due to non-compliance with the arrangement and size (circle diameter) of the roundabouts discussed in this research. Therefore, the models used in this research are as follows:

1- HCM 2016 model, which has predicted the capacity for each lane arrangement.
2- FHWA model, which predicts capacity by linear regression.
3- TRRL model, which predicts capacity based on geometric characteristics.

In the process of comparing international models and observed capacities, the amount of predicted capacity of each model for each specific approach is deducted from the amount of observed capacity, and the different percentage of the predicted value is calculated. Roundabout elements are shown next to each other in Figure (4). The comparison of these models based on the RMSE index is shown in Table (3). The RMSE value is an absolute measure of proportionality known as the square root of variance. RMSE can also be interpreted as a standard deviation from unexplained variance. The RMSE value indicates the standard deviation of the forecasted errors. Prediction errors are a measure of the distance between data points and the model line. In other words, RMSE is a measure of data scatter that states how much data are concentrated around the model line. Therefore, the lower the RMSE value, the better the model can predict the data.

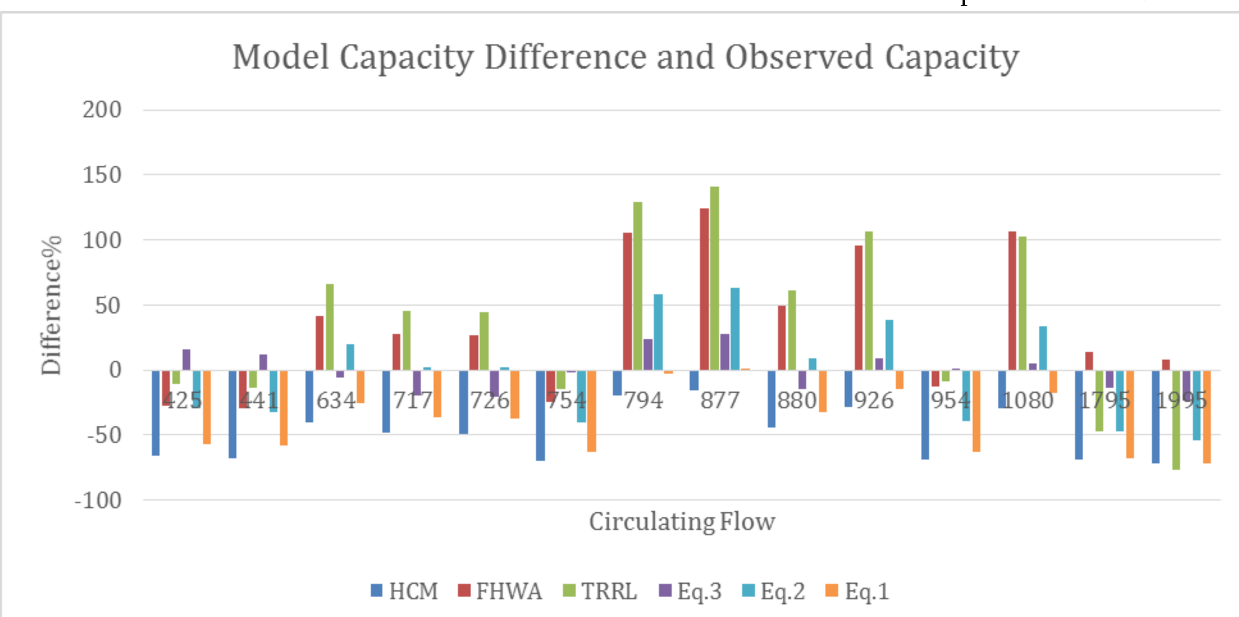

Figure 4. Comparison of the predicted capacity of international models and observed capacity

Table 3. RMSE value for each model

RMSE	Model
477	HCM
740	FHWA
437	TRRL
340	Eq.1
320	Eq.2
200	Eq.3

HCM 2016 models are based on the same general model presented in Report 572, developed based on newly collected data. Also, the mentioned models have different coefficients based on the arrangement of other lanes. Moreover, these models do not cover the structure of two entry lanes versus three circulating lanes. The model mentioned in this comparison has a better forecast than FHWA and TRRL models. It is noteworthy that HCM model has a better prognosis at medium flow rates (800-900 PCU / h) and is close to real values. It performs poorly for high and low circulation flows and has more than 50% fewer estimated values.

FHWA model gives a capacity prediction based on linear regression, which, as compared to the comparison, has a perfect fit for Iran's situation. As found in RMSE value, the standard deviation of the prediction errors is very high. It can have a better prediction in high circulating volumes than the models mentioned in this comparison, but in low to medium circulating volumes, it shows a very high percentage of errors.

TRRL model is a linear regression model that is predicted as the best regression model in the UK and expects the capacity of the entry approach based on geometric and flow variables (such as entry width, entry degree, entry radius, and circulating flow versus entry approach, etc). Due to the limitations of the model's parameters, this model can predict all selected approaches. However, this model has fewer prediction errors than the standard deviation of HCM and FHWA models predicting capacity in medium and high flows. It performs very poorly and estimates capacity more than 100% higher than the observed circulating flow values.

The first model proposed in this study, which assumes geometric characteristics, shows that the standard deviation of prediction errors has been significantly reduced compared to international models. Still, on average, in all circulating volumes, the entry capacity is estimated to be about 50% lower. In the second model proposed in this study, by adding the diameter of the central island to the relationship, it can be seen that the standard deviation of forecasting errors is slightly reduced. In average circulating volumes, they estimate about 50% more than the actual capacity conditions. Compared to the previous model, it can be said that they do not have any unique advantages over each other. In the final and third model obtained in this study, which has been developed by considering the diameter of the central island and the weaving width, it can be seen that in addition to significantly reducing the standard deviation of forecast errors compared to previous models, the nose has been reduced by up to 20% and has performed better in predicting entry capacity in all ranges of circulating flow values.

It can be generally concluded that most models for predicting entry capacity in medium and high flow currents do not fit Iran's situation well. The capacity model presented in this study considers the diameter of the central island and the width of the interference zone. It has the best fit of Iran's conditions.

7. Effect on Entry Capacity Per Change in Geometric Variables

The relationship between the roundabouts' geometric elements under study and the entry capacity is examined in more detail in this section. As mentioned earlier, the entry capacity depends on two geometric components of the roundabout, namely the diameter of the central island and the weaving width. Each geometric element had a significant effect on the entry capacity. Therefore, a study has been conducted to investigate the change in entry capacity to increase or decrease the geometric characteristic. Figures (5) and (6) show the nature of changes in geometric features.

Examining the results and diagrams, it can be seen that for each increase in the diameter of the central island and each increase of 125 PCU / h in the flow, entry capacity decreases by about 12%, and for each meter increase in the diameter of the central island, the capacity increases by about 6%. In general, it can be concluded that with the increase of the diameter of the central island, the ratio of flow to capacity has decreased, and as a result, the capacity has increased. At any rate, weaving width decreases by about 11% of entry capacity for each increase of 125 PCU / h during circulating flow, and each meter increase in the width of the interference zone, a 35% increase in entry capacity is observed. In general, it can be concluded that with increasing weaving width, more and smoother flow passes around the roundabout, and the roundabout capacity is increased.

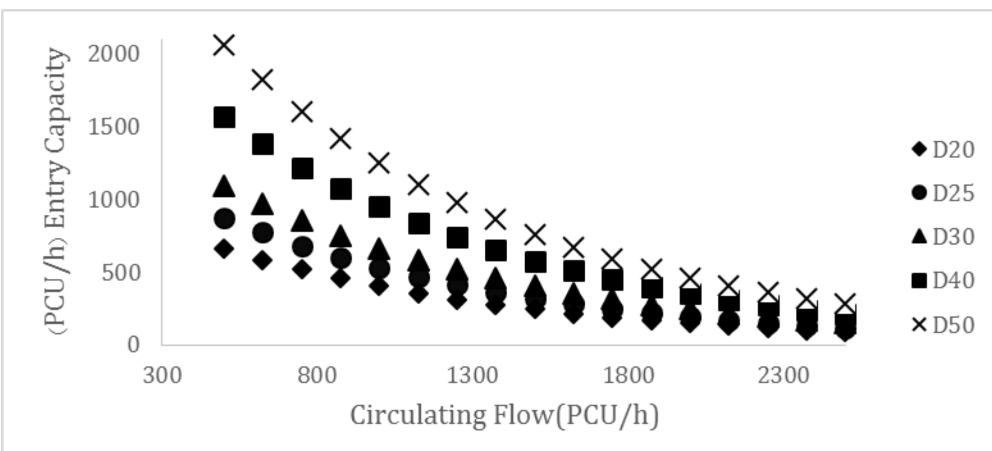

Figure 5. The effect of changes in the diameter of the central island on entry capacity

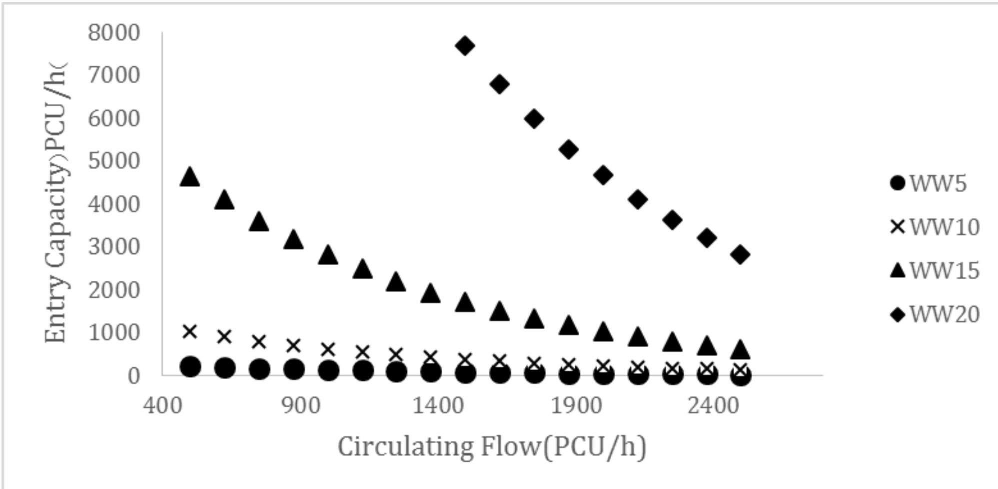

Figure 6. Effect of Weaving width changes on entry capacity

8. Conclusion

This study was conducted to determine the practical geometric factors of roundabout performance in 2 cities of Iran. An experimental model for the capacity of roundabouts with geometric parameters as explanatory variables was finalized and produced. Items that can be concluded from the study are as follow:

1- The relationship between entry flow and circulating flow was found exponentially for the best fitting model.

2- Among the different modes of modeling, the entry capacity determination model, which is described by the variables of circulating flow, the diameter of the central island, and weaving width, is the best statistically and in the stage validation of the model. It was found that this model had better results compared to other international models.

3- Geometric variables, including the diameter of the central island and the weaving width, showed a significant effect on capacity. It was observed that with each meter increase in the diameter of the central island, the entry capacity of the roundabout increased by 6%. Also, with each meter increase in the weaving width, the entry capacity has increased by 35%.

4- Validation of the model proved that the proposed model is suitable for the (undersaturated or oversaturated) flow conditions for most roundabouts. In some cases, capacity assessments were underestimated. When the flow rate is too high, this may be due to the collision and interference of many vehicles in the mainstream, thus reducing the entry flow. In general, this model provides favorable results for Iran’s roundabouts.

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