



CAPACITY ANALYSIS ON MULTI-LANE ROUNDABOUTS: AN EVALUATION WITH HIGHWAY CAPACITY MANUAL 2010 CAPACITY MODEL

ÇOKŞERİTLİ DÖNEL KAVŞAKLARDA KAPASİTE ANALİZİ: HIGHWAY CAPACITY MANUAL 2010 KAPASİTE MODELİYLE BİR DEĞERLENDİRME

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Abstract

In this study, capacity estimations with the incorporation of Highway Capacity Manual (HCM) 2010 method are evaluated. Parameter based sensitivity analysis on calculations with the new HCM formula and a comparative evaluation of the new methodology with two most common capacity analysis methods, i.e., the method of critical gap acceptance and the method of regression analysis, are performed. Maximum and minimum headway intervals of follow up time and critical gap parameters are alternated within the sensitivity analysis. The Transport Research Laboratory formula for regression and Australian formula for gap acceptance method are considered in comparison. Relative comparisons of predictions on capacity by HCM2010 method, regression analysis and gap acceptance method are presented considering field data obtained by observations at two roundabouts in Izmir, Turkey. The results of the study show that the HCM2010 formula led to lower capacity estimates than regression analysis and higher estimates than the gap acceptance method. Regarding the real capacity observations under high circulating flow-rates the HCM2010 method yielded to more appropriate results than the regression method. In addition to comparisons, studies on the sensitivity analysis show that entry capacity estimates possess sharper changes as smaller follow up headways are accepted.

Keywords: Traffic engineering, Roundabouts.

Öz

Bu çalışmada, genel kabul görmüş çok şeritli dönel kavşak kapasite hesap yöntemlerinin uygulanabilirliği, yeni Highway Capacity Manual (HCM) 2010 yöntemiyle karşılaştırılmıştır. Yöntemlerden elde edilen sonuçlar, yerel çalışmalardan toplanan verilerin ışığında değerlendirilmiştir. Karşılaştırma için regresyon analiz yöntemini temsilen Transportation Research Laboratory (TRL) formülasyonu, Kritik aralık kabulü yöntemini temsilen Avusturya Hesap Yöntemi seçilmiştir. Bunlara ek olarak, sınırlı öncelik ve ters öncelik koşullarının göz önünde bulundurulduğu kalibre edilmiş kritik aralık yöntemi ve HCM 2010 da yerel uygulamalar için öngörülen kalibre edilmiş formüller ile hesaplamalar yapılmış ve HCM 2010'un olağan değerleriyle karşılaştırılmıştır. Çalışmanın sonucunda elde edilenler, kritik aralık kabul yöntemi ve regresyon yönteminin HCM 2010 olağan değerlerine kıyasla genellikle daha yüksek sonuçlar verdiğini göstermiştir. Yöntemler arasında yapılan regresyon analizleri sonucu, özellikle yüksek dönen akımlar altında kritik aralık kabul yönteminin HCM 2010 yönteminden daha uygun sonuçlar verdiği görülmüştür. Ancak HCM 2010'da yerel uygulamalar için kalibrasyon yapılmasını sağlayan formülasyon sonucunda elde edilenler, olağan formülasyonun verdiği düşük kapasite tahminlerini daha uygun değerlere yükseltmiştir.

Anahtar kelimeler: Trafik mühendisliği, Yuvarlakada kavşaklar.

1 Introduction

A modern roundabout is a type of intersection design that controls and diverts traffic flow around a central island. Roundabouts are differentiated from other traffic circles in traffic control, pedestrian access, parking and direction of circulation features. Efficient use of capacity on roundabout design brings higher functional performance. Roundabouts are preferred as a part of the transportation system for preventing lock-up under high traffic volumes and improving safety performance. Various studies investigating the safety performance are made in Europe and United states. Federal Highway Administration (FHWA)'s guide gathered together the mean reduction of crashes after building roundabout [1].

This paper discusses the parameter sensitivity of new Highway Capacity Manual (HCM) 2010 formula and comparison of new methodology with critical gap acceptance and regression models considering field observations. Australian model summarized in [2] is used for gap acceptance formula. United Kingdom model also known as Transportation Research Laboratory (TRL) method is used for regression

analysis. Obtained results are compared with in site data collected from two roundabouts in [3].

In the first part, fundamentals of design and traffic flows at roundabouts are stated. Secondly, capacity analysis used in comparison, HCM 2010 [4], gap acceptance and regression methods are introduced. In the following section HCM 2010 is compared with both methods and observed data. In the last part of the study sensitivity analysis of HCM 2010 on parameters follow-up time, T_f , and critical gap, T_c , are investigated.

Considering the validity of applied methods it is useful to mention the design differences between investigated sites in Turkey and typical sites used to develop compared models in the US, Australia and UK. The findings represent application of those models to Turkish data only for the studied roundabouts and are not generalized for different sites.

2 Fundamentals of Design and Traffic Flows at Roundabouts

A well designed roundabout ensures safety for all types of vehicles those defined in user category. Layout of the

roundabout reduces vehicle speed and keeps circulating vehicles in low speed through the roundabout. Available sight distances for entering vehicles are also obtained from roundabout geometry to observe vehicles in conflicting flow and movements of non-motorized users.

Three fundamental elements must be determined in the preliminary design stage; the optimal roundabout size, position, alignment and arrangement of approach leg [1].

2.1 Roundabout Design

Geometric design elements have significant importance on operational performance and safety objectives of a roundabout. In addition to individual importance of each element, the interaction between each component should be studied for a well-designed layout. Geometric design elements detailed in the following topics are; Inscribed circle diameter, entry width, circulatory roadway, central island, entry curves, exit curves, splitter island and stopping sight distance. Table 1 presents the geometric parameters and their symbols commonly used in regression models. Figure 1 depicts a roundabout geometry with elements used in TRL formulae.

Table 1: Geometric parameters used by the regression models.

Parameter	Description	Range Values (m)
e	Entry width	3.6–16.5
v	Lane width	1.9- 12.5
e'	Previous entry width	3.6–15.0
v'	Previous lane width	2.9–12.5
u	Circle width	4.9–22.7
l, l'	Flare mean length	1–∞
S	Sharpness of the flare	0–2–9
r	Entry bend radius	3.4–∞
Φ	Entry angle	0–77°
D = Dext	Inscribed circle diameter	13.5–171.6
W	Exchange section width	7.0–26.0
L	Exchange section length	9.0–86.0

Geometric elements showed in the table above are also showed in Figure 1 those taken from the original work of Kimber ([5]).

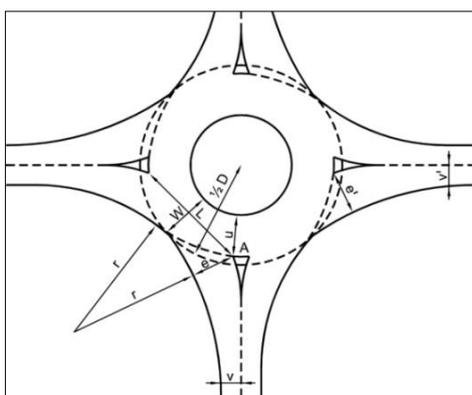


Figure 1: Geometric elements used in the TRL formula.

2.2 Traffic Flows at Roundabouts

For a given volume of circulating vehicles, capacity is defined as the maximum number of vehicles that can reasonably enter the roundabout within 1 hour. The entry/circulating (Q_e/Q_c) flow ratio is also useful to express the entry capacity relation of the roundabout with circulation flow. Basic parameters

defined inside circulating stream are explained in the following sections.

2.2.1 Basic Definitions

The interval between successive vehicles in a traffic lane as they pass a point on the highway in terms of time is named 'headway'. It is measured in seconds, from front bumper to front bumper of vehicles.

Gap is the headway between two consecutive vehicles passing the same reference point in the circulating stream. If an entering vehicle on the approaching leg arrives at the yield bar after the gap has already started, the remainder of the gap is called lag.

The minimum gap in terms of time that is acceptable to the entering stream driver to enter the roundabout, is called critical headway (or critical gap), T_c . The traditional gap acceptance method assumes that the drivers of the approach lane accept any gap greater or equal to the critical gap and reject any gap smaller than the critical gap [6]. Follow-up time, T_f , is the additional time required after the critical gap for following vehicles to enter the roundabout. Every driver can accept different gaps. It is possible to encounter such circumstances that a critical gap much longer than accepted by a driver could be rejected by another one [7].

2.2.2 Merging Conditions

Hangring defines gap forcing as a situation that vehicles entering the circulating flow use so small gaps that vehicles in the circulating flow are forced to give way and have to decelerate or completely stop [8]. In addition to gap forcing it is also possible to define limited priority and reverse priority as merging systems those can occur under over saturated conditions. At high levels of both entering and conflicting flow HCM 2010 defines limited priority as a condition which circulating traffic adjusts its headways to allow entering vehicles to enter and reverse priority as a condition which entering traffic forces circulating traffic to yield [4].

2.2.3 Capacity Analysis of Roundabouts

Most of the European countries and US formed their own capacity formulas according to their needs and highway standards. The consideration parameter in each formula changes with different methodologies. Two main methodologies, regression analysis and gap acceptance theory are accepted. In Germany and Switzerland Brilon and Bovy formulations consider the number of circle lanes and leg lanes. In UK detailed roundabout geometry is taken into account. In addition to these geometric aspects, the users' behaviors, psycho-technical times, T_c , critical gap, and follow-up time, T_f , are also used by France, Germany and US in improved capacity formulations.

Specifically, a series of works have been being conducted considering traffic circles in Turkey including ultimate capacity determination for single-lane roundabouts [9],[10], comparative evaluation of a series of capacity [3],[11] and delay measure [12] estimation methods, and impact of traffic composition on roundabout and merging flow capacity [13],[14].

3 Capacity Analysis: A Case Study

The case study in this paper presents a brief comparison of HCM 2010 formulation with regression and gap acceptance theories. Methodologies are discussed considering field data.

Additionally, parametric sensitivity of HCM 2010 formulation is studied as in the following.

3.1 Methods Used

The HCM 2010 [4], the linear Transport and Road Research Laboratory (TRRL) capacity formula [5] and the gap acceptance model [2] are used in comparative evaluations.

3.1.1 Highway Capacity Manual 2010 Model

HCM 2010, the fifth edition, developed new methodologies for evaluating roundabout performance. In difference to HCM 2000 edition, multilane roundabouts with up to two entry lanes and one bypass lane per approach were considered in capacity estimates. New method of HCM 2010 presents a lane based capacity model with combination of a simple lane based regression and gap acceptance models for both single and double lane roundabouts [4]. Akçelik describes new capacity model as a nonlinear empirical (regression) model with a theoretical basis in gap acceptance that covers both regression and gap acceptance theory as expressed in the Eq. (1) [15];

$$C = f_{HVe} \cdot f_p \cdot f_A \cdot A \cdot e^{-(B/f_B)Q_c} \quad (1)$$

Where; f_{HVe} is heavy vehicle factor for entry lane capacity, f_p is pedestrian factor for the effect of pedestrians crossing in front of entry lanes. f_A and f_B are adjustment factors for parameter A and B respectively where, $f_A=f_B$ means T_c/T_f is kept unchanged. Q_c' is circulating flow rate in front of the entry (adjusted for heavy vehicles) in pcu/h. f_{HVe} can be calculated by Eq. (2);

$$f_{HVe} = \frac{1}{1 + P_T(E_T - 1)} \quad \text{in case } E_T > 1 \quad (2)$$

Where E_T is the passenger car equivalent of a heavy vehicle for gap acceptance theory in pcu/veh and P_T is the proportion of heavy vehicles in the entry lane. Adjusted Q_c' can be determined by Eq. (3);

$$Q_c' = \frac{Q_c}{f_{HVe}} \quad (3)$$

Where Q_c' is the adjusted circulating flow rate in pcu/h, Q_c is the circulating flow rate in veh/h and f_{HVe} is heavy vehicle factor. It is possible to calculate f_{HVe} with Eq. (3) by adjusting P_T to circulating lane ratios. HCM defines default values shown in the Table 2 and Table 3 for capacity models according to observations made at US roundabouts in 2003 [4].

Table 2: A and B values for Single-lane circulating stream [4].

Single lane circulating stream($n_c=1$)	A	B
Single lane entry	1130	0.00100
Multilane entry	1130	0.00100

In addition to generalized formulas, it is possible to calibrate equation with local parameters. A and B parameters could be adjusted according to follow up time and critical headway with Eq. (4) and Eq. (5).

$$A = 3600/T_f \quad (4)$$

$$B = T_o/3600 = (T_c - 0.5T_f)/3600 \quad (5)$$

Where T_o is the parameter that relates critical gap and follow up time parameters in s unit, T_f is follow-up headway and T_c is critical gap headway.

Table 3: A and B values for Multi-lane circulating stream [4].

Multilane circulating stream ($n_c > 1$)	A	B
Single-lane entry	1130	0.00070
Multilane entry	Dominant lane (right)	1130 0.00070
	Subdominant lane (left)	1130 0.00075

3.1.2 Regression Model

The relationship defining the "Linear Capacity formula" by means of capacity and entry flow is proposed in [5]. TRRL expresses the capacity of a roundabout as a function of the leg and geometric features of the circulating flow in the circle, Q_c , in front of the entry. The relevant entry capacity formula is shown in the following Eq. (6) in a linear form.

$$C = k(F - f_c \cdot Q_c) \quad (6)$$

Where:

$$F = 303 \cdot x_2 \quad (7)$$

$$f_c = 0.210 \cdot t_D \cdot (1 + 0.2 \cdot x_2) \quad (8)$$

$$k = 1 - 0.00347 \cdot (\Phi - 30) - 0.978 \cdot (1/r - 0.05) \quad (9)$$

$$t_D = 1 + 1/(2 \cdot (1 + \exp(D - 60)/10)) \quad (10)$$

$$x_2 = v + ((e - v)/(1 + 2 \cdot S)) \quad (11)$$

$$S = (e - v)/1 \quad (12)$$

In this formula roundabout geometric elements are used as input and the disturbing flow, Q_d , is directly expressed by circulating flow, Q_c .

3.1.3 Gap Acceptance Model

The guide by Austroads [16] is the basic design guide for roundabouts. Australian model is summarized on the basis of gap acceptance methodology in [2]. Australian studies examined multilane roundabouts capacity for each entry lane those could differ in capacity. The lane with the higher capacity named dominant stream and other lanes called subdominant stream. General capacity formula of gap acceptance method is shown by Eq. (13).

$$q_e = q_c \cdot \int_0^\infty f(t) \cdot g(t) \cdot dt \quad (13)$$

Where q_e is the entry capacity in veh/s, q_c is the circulating stream volume in veh/s, $f(t)$ is the density function for the distribution of gaps in the circulating stream and $g(t)$ is the number of entering stream vehicles those can enter into the circulating stream in the time gap sized "t" [17]. Australian entry capacity formula built in [18] is given by Eq. (14).

$$Q_{e\max} = \max(f_{od}, Q_g, Q_m) \quad (14)$$

Where;

$$Q_g = \frac{3600}{T_f} \cdot \left(1 - \Delta \cdot \frac{q_c}{3600} + 0.5 \cdot T_f \cdot \alpha \cdot \frac{q_c}{3600} \right) \cdot \exp(-\lambda \cdot (T_c - \Delta_c)) \quad (15)$$

$$Q_m = \min(Q_e, 60 \cdot n_m) \quad (16)$$

$$f_{od} = 1 - f_{qc} \cdot (p_{qd} \cdot p_{cd}) \quad (17)$$

Q_e is the capacity of the entry lane in veh/h, Q_g is minimum capacity estimate using the gap acceptance method in veh/h, Q_m is minimum capacity in veh/h, q_c is total circulating flow rate flow in pcu/h, n_m is minimum number of vehicles can enter the circulating stream under heavy flow conditions in veh/min, f_{od} is origin destination adjustment factor, f_{qc} is calibration parameter, p_{cd} and p_{qd} are proportion of the total roundabout circulating flow that originated from the dominant lane and proportion of queued vehicles on the dominant approaching lane respectively, n_c is number of circulating flow lanes, Δ_c is minimum intra-bunch headway in circulating stream which is 2.0 s for $n_c=1$ and 1.2s for $n_c=2$ and λ is arrival headway distribution factor. Various definitions exist for λ . In [19] defined λ is defined as decay constant as given by Eq. (18).

$$\lambda = \frac{\alpha \cdot q_c}{(1 - \Delta \cdot q_c)} \quad (18)$$

Different equations exist to define the proportion of free vehicles α . Eq. (19) in [20] is used to determine α value.

$$\alpha = \frac{(1 - \Delta \cdot q_c)}{(1 - (1 - k_d) \Delta \cdot q_c)} \quad (19)$$

Where k_d is traffic delay/bunching parameter. The value suggested for k_d is 2.2 for roundabouts. f_{od} equations according to circulating lane number are given in the Table 4.

Table 4: f_{od} relations according to circulating lane number.

Single-lane Circulating Flow	Multi-lane Circulating Flow	In Case
$0.04 + 0.00015q_c$	$0.04 + 0.00015q_c$	$q_c < 600$
$0.0007q_c - 0.29$		$600 \leq q_c \leq 1200$
	$0.00035q_c - 0.08$	$600 \leq q_c \leq 1800$
55		$q_c > 1200$
	55	$q_c > 1800$

T_f and T_c are follow-up headway and critical gap. Follow-up headways are calculated for dominant and subdominant lane with following Eq. (21) and Eq. (22) in [21] respectively.

$$T_{fdom} = 3.37 - 0.021 \cdot D_i + 0.89 \cdot 10^{-4} \cdot D_i^2 - 0.395 \cdot n_e + 0.388 \cdot n_c - 0.000394 \cdot q_c \quad (20)$$

$$T_{fsub} = 2.149 + (0.5135 \cdot T_{fdom} - 0.8735) \cdot r_{ds} \quad (21)$$

Where, D_i is inscribed circle diameter in m, n_e is the number of entry lanes and r_{ds} is ratio of dominant to subdominant q_d/q_s flow rate. The critical gap is calculated for dominant and subdominant lane with following Eq. (22).

$$T_c = T_f \cdot \left(\frac{3.6135 - 3.137 \cdot 10^{-4} \cdot q_c}{-0.339 \cdot w_L - 0.2775 \cdot n_c} \right) \text{ for } q_c \leq 1200 \quad (22)$$

$$T_c = (3.2371 - 0.339 \cdot w_L - 0.2775 \cdot n_c) \cdot T_f \text{ for } q_c > 1200 \quad (23)$$

Where w_L is the average entry lane width in meters.

3.2 Field Data

The data for the evaluation of HCM 2010 capacity model is obtained from Tanyel's [3] studies on Montro and Lozan roundabouts. Both intersections are located in Central İzmir. Geometric features of the Lozan and Montro roundabouts are given in Table 5.

Table 5: Geometric Features of Lozan and Montro Roundabouts [3].

GEOMETRIC FEATURES	MONTRO	LOZAN
Inscribed Circle Diameter (D_i)	65.00 m	67.00 m
Entry lane number (n_e)	2	2
Entry lane width (w_e)	3.00 m	3.00 m
Exit lane width ($n_u n_u$)	-	3.00 m
Splitter Island width (w_{si})	-	9.00 m
Circulatory Lane number (n_c)	3	3
Circulatory Roadway width (w_c)	20.00 m	20.00 m
Entry angle (ϕ)	46	54

The schematic presentation of Lozan and Montro Roundabouts are given in the Figure 2a and 2b respectively. On Lozan Roundabout, Alsancak approach shown in Figure 2 with number 3, is observed. There are two entering and two exiting lanes on Alsancak approach split with a 7.00 m refuge and approach lane widths are 3.00 m.

On Montro Roundabout, Cumhuriyet approach shown in Figure 2b with number 5, is observed. There are two entering lanes on Cumhuriyet approach with 3.00 m width.

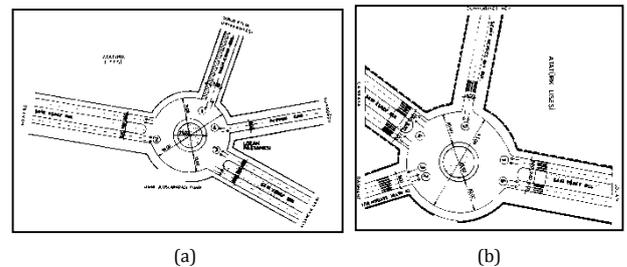


Figure 2: a) Lozan Roundabout [3], b) Montro Roundabout [3].

Test data used in the evaluations are maintained from observations made by Tanyel [3]. According to [22], the best way to determine the capacity of a roundabout is the direct measurement of the maximum incoming vehicle number from approaching lanes with observations. In order to obtain such kind of data there should be a constant queue of vehicles waiting on the approaching leg for 30 minutes long. Under these circumstances, data of 1 min and 5 min periods are adequate for capacity estimates [22].

Data collected from the observations of Lozan and Montro consist of 1 min periods those are 46 min and 45 min groups respectively. According to recordings made at mornings and evenings peak hours; circulatory flow rate in veh/h and veh/min, number of entering vehicles in veh/h and veh/min, circulatory roadway headways in sec, follow-up times in sec and critical gap headways in sec data are obtained.

3.3 Numerical Analysis

As previously mentioned, TRL method is the representative capacity analysis method for regression models, therefore it is chosen for comparison of HCM 2010 with a regression model. TRL entry capacity formula, Eq. (6) is used for Lozan and Montro Roundabouts.

Regression formula calculated according to geometric characteristics of each roundabout. Figure 3 and Figure 4 show observed field data with Q_e , the results of regression analysis with Q_{ecal} and predicted results of HCM 2010 with Q_{eHCM} for Lozan and Montro roundabouts respectively.

A linear regression is done between Q_e observed values and estimated values of regression analysis and HCM 2010 values. The linear relationship and the coefficient of determination, 'r²' for the regression and the HCM methods are respectively given by equations 24 and 25.

$$Q_{epredicted} = 1.2635 \cdot Q_{eobs} - 55.01 \text{ with } r^2 = 0.59 \quad (24)$$

$$Q_{epredicted} = 0.7449 \cdot Q_{eobs} + 111.95 \text{ with } r^2 = 0.645 \quad (25)$$

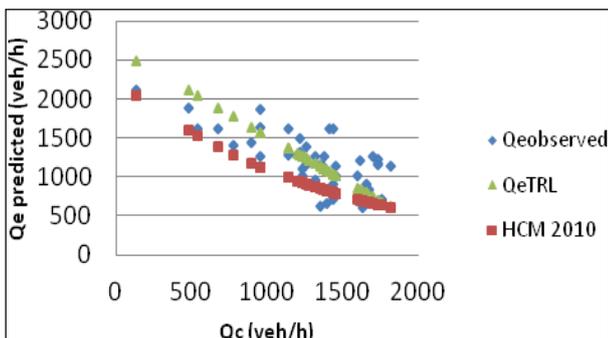


Figure 3: Comparison of capacity models for Lozan roundabout.

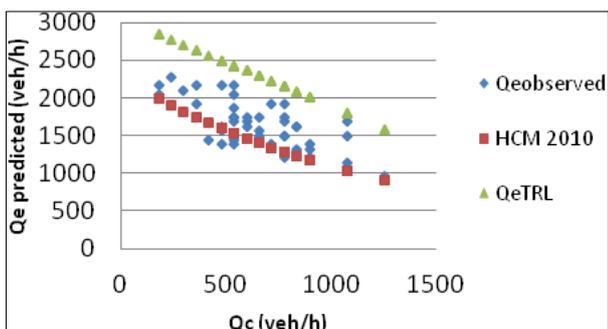


Figure 4: Comparison of capacity models for Montro roundabout.

As can be seen from the figures, HCM 2010 generally gives lower capacity estimates than regression analysis. Especially in low circulating flow, in Lozan, HCM 2010 gave more accurate results in comparison with linear regression. Under higher circulating flow conditions, in Montro, HCM 2010 model derived slightly under the observed conditions where the scatter of the TRL model estimates define more appropriate Q_e values.

For the evaluation of capacity according to gap acceptance method, Troutbeck's T_c and T_f formulations for dominant and sub dominant lanes are used. Exiting flow effect on the capacity is neglected. Mean values of evaluated critical

headway and follow up headways for each roundabout are shown in the Table 6.

Table 6: Mean T_c and T_f values.

Roundabout	$T_{f\ dom}$ (s)	$T_{f\ sub}$ (s)	T_{dom} (s)	T_{sub} (s)
Lozan	2.492	2.626	3.049	3.210
Montrö	2.273	2.494	2.848	3.120

Troutbeck's formula in Eq. (15) is used in this study for evaluating dominant and subdominant lane capacities and Eq. (19) for proportion of free vehicles for each data group. Predicted capacity values were determined by summation of dominant and subdominant lane capacities. Decay constants were calculated with Eq. (18) defined for roundabouts in Turkey in [19].

Gap acceptance method and HCM 2010 results for Lozan and Montro roundabouts are shown in the Figure 5 and Figure 6 respectively.

A linear regression is done between observed values and estimated values of gap acceptance analysis and HCM 2010. The linear relationship and the coefficient of determination, 'r²' for the gap acceptance and the HCM methods are respectively given by equations 26 and 27.

$$Q_{epredicted} = 0.7236 \cdot Q_{eobs} + 662.02 \text{ with } r^2 = 0.615 \quad (26)$$

$$Q_{epredicted} = 0.7486 \cdot Q_{eobs} + 105.59 \text{ with } r^2 = 0.651 \quad (27)$$

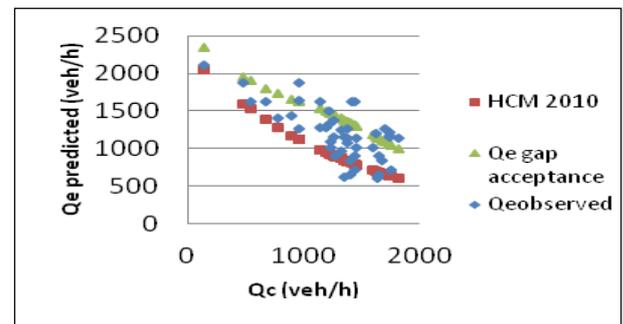


Figure 5: Comparison of capacity models for Lozan Roundabout.

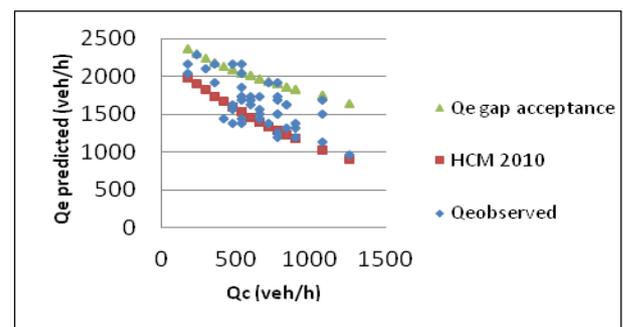


Figure 6: Comparison of capacity models for Montro Roundabout.

As can be seen from the figures, HCM 2010 generally gives lower capacity estimates than gap acceptance analysis. In low circulating flow HCM 2010 gave more accurate results in comparison with gap acceptance. Under higher circulating flow conditions HCM 2010 model derived slightly under the observed conditions.

Besides HCM 2010 default values seem to give lower capacity estimates than gap acceptance and regression methods, it should not be forgotten that it is also possible to calibrate HCM formulation with Eq. (4) and Eq. (3). The potential impact of T_c and T_f in capacity estimate is examined by varying the two main parameters between minimum and maximum limits under different circulating flows (Q_c). Circulating flow values are fictitious those range such 1 veh/h, 100 veh/h, 200 veh/h to 1600 veh/h with 100 veh/h intervals. Change of capacity estimates with parameters T_f and T_c are shown in the Figure 7a and Figure 7b respectively.

As can be seen from above figures, HCM 2010 calibrated formulation estimates higher capacity for entry if smaller critical gap and follow up values are accepted by drivers.

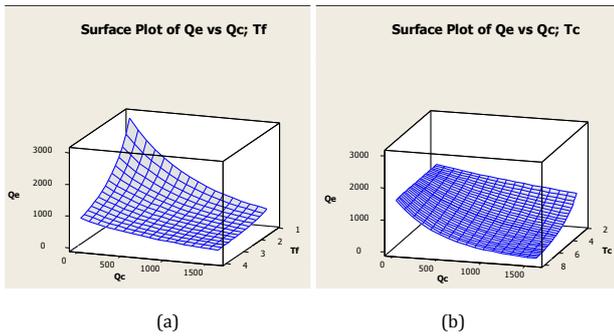


Figure 7: Change of capacity estimates with parameter a) T_f , b) T_c .

4 Conclusions

In this paper, data obtained from one approaching leg of two roundabouts in Izmir are studied in order to make comparison between HCM 2010 default values, regression model an gap acceptance model.

Gap acceptance and regression models generally resulted in higher values than HCM2010 default value formulation. Especially for high circulating volumes gap acceptance methodology is found to be more accurate than HCM2010 default value estimations and regression analysis. Lower capacity estimate of HCM2010 under high traffic volumes could be regenerated by using calibrated formulations. Results obtained are valid for sample roundabouts because of site specific characteristics.

HCM 2010 default value formulations are found to be more appropriate for lower circulating volumes. However UK model might be more applicable in relation to the range of geometric conditions those could be adjusted for studied roundabouts. Within the calibrated model of HCM 2010 it is possible to obtain specialized results for different site conditions using T_c and T_f values.

In order to obtain better correlation coefficients for studied models, reversal priority and gap forcing conditions should be considered during the evaluations. In this study the obtained data groups are limited. To achieve better results the number of examples should be increased and a detailed research should be done on the effect of driver behaviors for capacity estimation.

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