Traffic Circulation Efficiency Analysis of Elliptical Roundabouts

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***Abstract*— This paper investigates the impact of a roundabout's central island geometry on operational performance. A case study roundabout with an elliptical central island, characterized by major and minor axes of 63 and 44 meters respectively, is examined. Using SIDRA intersection software, two simulation models were developed, one with an elliptical shape and the other circular. The investigation commenced by assigning peak traffic volumes to both models, followed by the generation of twelve diverse scenarios. These scenarios encompassed gradual increases in lane volumes, spanning from levels of service A to F. Each approach received 100% of the assigned volume for one run and 75% for the other, with this allocation alternating in successive runs. The results demonstrated that at high degrees of saturation, the elliptical roundabout outperformed the circular roundabout in terms of delay and capacity. The performance index of the elliptical roundabout was 16.9% lower than that of the circular roundabout, confirming its superior performance. Moreover, recognizing the importance of accommodating heavy vehicles in urban settings, a parametric study was conducted. Eight additional simulation scenarios, encompassing varying heavy vehicle percentage (HV%) were executed. Results indicated at higher HV% levels, particularly around 8% and 12%, control delay increases by 28.9% and 35.2% for elliptical and circular roundabouts, respectively. These results confirm that the performance of the elliptical roundabout outperforms the circular roundabout under various scenarios. However, it's crucial to highlight that the elliptical roundabout displayed higher susceptibility to increasing heavy vehicle percentages compared to the circular roundabout.**

***Index Terms*—Circular roundabout, Elliptical roundabout, Heavy vehicle percentage, Performance evaluation, Traffic simulation.**

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I. Introduction

The history of roundabouts dates back to the early 1900s when the first ones were established in Paris and New York. However, these initial attempts were intended as pedestrian traffic islands rather than efficient traffic management solutions. These early models led to traffic jams and accidents, revealing the need for improved designs. In 1966, the British government enacted legislation to guide the construction and utilization of roundabouts, marking a pivotal shift towards their modern form. This legislation played a significant role in reducing crashes and delays by about 40%, while enhancing roundabout capacity by approximately 10% (Moran, 2009).

A modern roundabout is characterized by a circular junction where traffic flows counterclockwise around a central island. It differs from traditional intersections as it lacks traffic signals or stop signs. Drivers entering a roundabout must yield to oncoming traffic, proceed through the junction, and exit onto their selected street (WSDOT, 2021; Qu, et al., 2014; Mohammed Ali, et al., 2023). This modern design not only enhances traffic flow but also elevates the aesthetics of roads while providing improved safety compared to conventional intersections. In modern roundabouts, traffic signals or stop signs are absent. When entering, drivers yield to oncoming traffic, proceed to the junction, and exit onto their chosen street (WSDOT, 2021). This design significantly improves traffic flow, enhances road esthetics, and ensures greater safety compared to traditional intersections.

Research by the University of Maine found a 39% reduction in crashes, a 76% decrease in injury-producing crashes, and a remarkable 90% reduction in collisions resulting in fatal or incapacitating injuries across a sample of 25 intersections converted into roundabouts. Similarly, (Davies, 2011) found that roundabouts not only improve safety but also possess the potential to reduce traffic delay by up to 75%.

The performance assessment of the roundabouts has been a focal point for researchers over the past few decades. (Sisiopiku and Oh, 2001) delved into the performance comparison between roundabouts and four-leg intersection using SIDRA package. This study considered diverse geometric configurations and traffic conditions. The results confirmed the general superiority of roundabouts in terms of higher capacities compared to other traffic control intersection types, such as yield control, two- and four-way stop control, and signal control. (Mabuchi and Nakamura, 2007) conducted a comparison between roundabouts and signalized intersections. Their results showed that when the approaching traffic volume is below 600 veh/h, roundabouts experience significantly fewer delay and traffic conflict issues compared to signalized intersections. In addition, the study found that as the difference in traffic volume between each approach increases, the performance of roundabouts decreases. (Al Momani, 2009) investigated the operational performance of roundabouts and pre-timed signalized intersections using MITSIMLab microscopic traffic simulator. This study utilized a virtual network for comparisons based on various traffic volume and green times for pre-timed signalized intersections. The results revealed that roundabouts statistically outperformed pre-timed signalized intersections across all traffic volumes. Similarly, (Tracz and Chodur, 2012) compared traffic performance of signalized intersection, signalized roundabouts, and signalized turbo roundabout. Their results showed that signalized turbo roundabouts exhibited enhanced safety and efficiency, even under the conditions of higher accident risk for public transport (buses and trams) when halting at bus/tram stop stations within the intersections.

In a more recent study, (Hatami and Aghayan, 2017) undertook a comparison of three types of roundabouts (modern, turbo, and elliptical roundabouts) with varying circulating widths and speed limits. Their simulations were conducted using Aimsun simulation software. However, the study faced limitations due to the overestimation of roundabout capacities derived from the simulation, impacting its practical applicability. In addition, the lack of clarity in the roundabout geometric design further hindered the study's relevance. (Mohamed, *et al*.., 2022) utilized the VISSIM simulator to simulate a mega elliptical roundabout on rural multilane highways. They considered various scenarios of mega elliptical roundabouts at different traffic flows for intersection entrances. The parameters of comparisons included minimum delay, minimum emissions, and minimum fuel consumption. The findings highlighted instances where the elliptical roundabout outperformed traditional interchanges (full cloverleaf), and they proposed the optimal time for transitioning from a mega elliptical roundabout to an interchange (full cloverleaf).

(Akçelik, 2011a) examined differences in capacities estimated by the HCM 2010 and SIDRA standard models for multilane roundabouts. The study emphasized the need to incorporate driver behavior parameters, as in the SIDRA standard method, into roundabout capacity models. Moreover, NCHRP 672(TRB, 2010b) emphasized that lane-by-lane modeling of roundabouts is pivotal for understanding the impact of roundabout geometry on the capacity. Other factors, such as lane width and number of lanes, were found to be of secondary significant. Continuing from his previous research (Akçelik, 2017) conducted an assessment of the HCM Edition 6 model and then comparing it with that of the HCM2010 and SIDRA standard capacity for roundabouts. In the light of results mentioned in this study, it can be concluded that there exists a broad consensus regarding the superior performance of roundabouts in terms of safety, traffic performance, vehicle time consumption, fuel consumption, and air pollution compared to other control modes.

There are various types of roundabouts categorized based on shape, configuration, and size: (i) Circular and elliptical roundabouts as the most prevalent shapes; (ii) configuration-wise, there exist mini roundabout, normal roundabout, and double roundabout; and (iii) concerning size, roundabouts can be single-lane or multi-lane (AASHTO, 2011). In Kurdistan Region of Iraq, the proliferation of roundabouts is rapidly increasing, especially within newly developed urban areas and even along high-speed rural highways. This surge necessitates a well-structured and effectively managed plan to regulate the flow of incoming traffic at these roundabouts. Consequently, this study focuses on assessing the capacity and efficiency of a standard multilane elliptical roundabout. For this purpose, Shari Spi intersection situated in the eastern-north of Sulaymaniah city is selected as a case study location. The selection of Shari Spi intersection is rooted in its distinct attributes, being the sole elliptical roundabout within the city featuring multiple entry points and high traffic volume.

Furthermore, the roundabout experiences noticeable traffic congestion issues on its approaches, particularly during peak periods. Fig. 1 provides a visual representation of the chosen roundabout.

The rest of this research is organized as follows. Section 2 presents the framework of the proposed methodology with the detailed steps of data collection. Section 3 demonstrates calibration, analysis results, and comparisons between different roundabout shapes. Finally, Section 4 provides concluding remarks on the study.

II. Methodology

This study was conducted by collecting traffic volume from a roundabout with an elliptical central island using

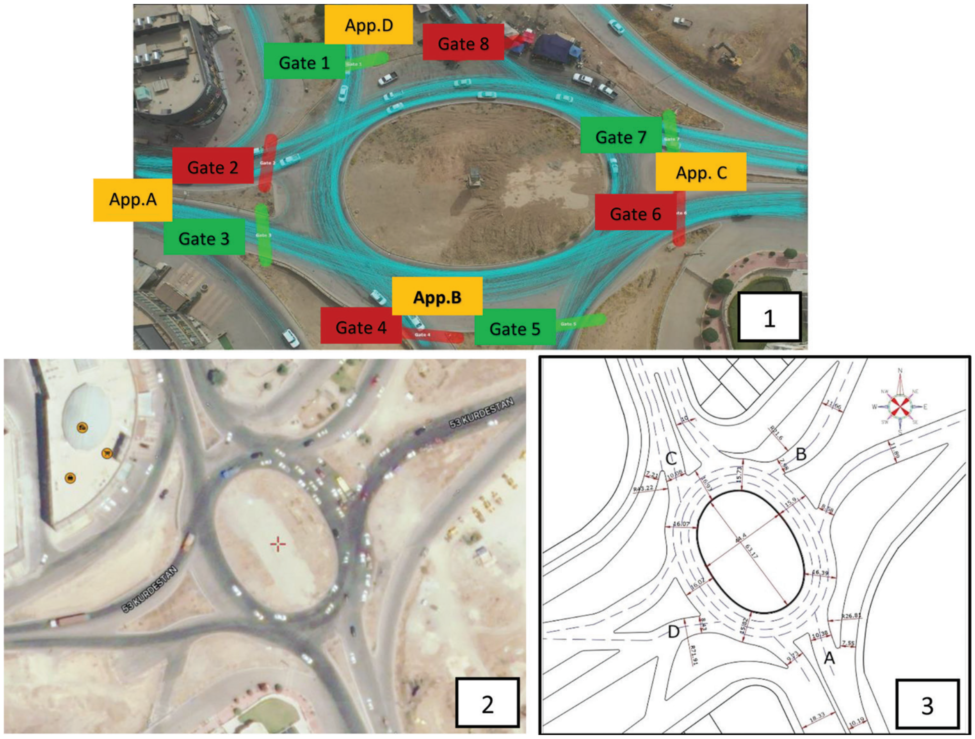

Fig. 1: Shari Spi roundabout (1-taken from drone camera, 2-Google map, 3- AutoCAD 2D).

video recording for approximately 5 h of the morning peak period. The determination of the peak hour was based on a comprehensive and pilot study over various days of different weeks spanning two distinct months. This selection ensured that the generated traffic volume was at its highest.

The turning proportions for each approach movements were calculated using Corel studio software. This approach was necessary because, at roundabouts, when lane movements mix with the circulating volumes, it becomes challenging to track individual car movements effectively. Table I shows the peak hour volume and flow rate of each approach roads.

This study utilized Sidra Intersection software as the simulation tool. Sidra intersection is an advanced, lane-based micro-analytical tool that is used worldwide for the purpose of design and evaluation of individual intersections and networks. The software offers a range of design and evaluation measures, including capacity, level of service (LOS), and various performance metrics such as delay, queue length, stops per vehicle, and for pedestrians, as well as factors like fuel consumption, pollutant emissions, and operational cost. SIDRA intersection 8.0, in particular, offers significant improvements in network modeling and processing (Akçelik, 2018). Furthermore, this software version, especially for roundabout, exhibits remarkable capabilities compared to some other software in use. It is recognized by Highway Capacity Manual and the TRB Roundabout Guide (TRB, 2010b). This software version includes the SIDRA Standard roundabout capacity model, alongside HCM and other common models. It takes into account roundabout geometry parameters, including roundabout diameter, entry radius, entry angle, entry lane width, circulating lane width, the number of entry lanes, and circulating lanes, as well as

TABLE I
Summary of 5 h traffic volume (peak 15 min of each day)

Summary of peak hour traffic volume					
Time	Duration	Approach A	Approach B	Approach C	Approach D
07:51–08:06	15 min	147	261	275	238
08:06–08:21	15 min	157	239	302	281
08:21–08:36	15 min	175	201	293	320
08:36–08:51	15 min	141	233	234	304
Flow rate		700	1044	1208	1280

other geometric parameters, when calculating capacity. The capacity model offered in SIDRA intersection is based-on gap-acceptance theory and employs empirical (regression) equations to model gap-acceptance parameters including the effect of roundabout geometry. In contrast, the HCM 6 capacity model is an empirical (exponential regression) model firmly grounded in gap acceptance theory without taking roundabout geometry into consideration (Akçelik, 2011a, 2011b).

HCM2010 Capacity Model for two-lane entries conflicted by two circulating lanes given as follows (TRB, 2010a):

$$c_{e,R,pce} = 1130 e^{\left(-0.7x10^{-3}\right) v_{c,pce}} \quad (1)$$

$$c_{e,L,pce} = 1130 e^{\left(-0.7x10^{-3}\right) v_{c,pce}} \quad (2)$$

Where

$c_{e,R,pce}$ = *capacity of the right entry lane in* (pc/h)

$c_{e,L,pce}$ = *capacity of the left entry lane in* (pc/h)

$v_{c,pce}$ = *conflicting flow rate* (*total of both lanes*) *in* (pc/h)

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$$Q = s\ u \quad (3)$$

Where:

s = saturation flow rate (veh/h) and *u = unblocked time ratio*

For any gap-acceptance process, the saturation flow rate is

$$s = 3600/\beta \quad (4)$$

Where:

β = follow-up headway of the entry stream (sec.), and the unblocked time ratio is u = g/c, where g = average unblocked time (sec.) and c = average gap-acceptance cycle time (sec.)

The unblocked time ratio used in SIDRA roundabout model is calculated by;

$$u = \max\left\{u_{\min}, f_{od}\left(1-\Delta_c q_c + 0.5\beta\varphi_c q_c\right)e^{-\lambda(\alpha-\Delta_c)}\right\} \quad (5)$$

$$u_{\min} = Q_m / s \quad (6)$$

$$\lambda = \varphi_c q_c / (1-\Delta_c q_c) \text{ subject to } q_c \le 0.98/\Delta_c \quad (7)$$

Where:

u_{min} is the minimum value of the unblocked time ratio, f_{od} is the origin-destination factor, Q_m is the minimum capacity per lane (veh/h), s is the saturation flow rate (veh/h), β is follow-up headway (sec.) and α is critical gape (sec.) for the entering stream, φ_c is the intrabunch headway (sec.) and φ_c is the proportion unbunched for the circulating stream, and q_c is the circulating flow rate (pcu/s) (Akgelik and Besley, 2005).

Two roundabout models were created in this simulation software. The first model represented the existing study area with an elliptical central island, while the second model featured a roundabout with circular central of 63 m radius. This radius value was derived from the major axis of the elliptical central island in the existing model. Although the utilized version of SIDRA intersection was not capable of visually depicting the elliptical layout of the roundabout, the impact of the geometry was accounted for, and it was reflected in the output layouts. To evaluate the impact of the central island's shape on the performance of roundabout, several measures of effectiveness were compared. These measures included control delay, geometric delay, queue length, average travel time, speed efficiency, and performance index assessed at different levels of detail such as lane, movement, approach, and intersection.

III. Data Analysis And Results

A. Calibration

To ensure that the software's output accurately represents the real condition of the site, it must undergo calibration using *in situ* control delay parameter. Traffic data were collected over several hours at various time of the day to account for oversaturated and undersaturated conditions at the intersection. The data were extracted using Data from Sky platform (Fig. 1) and the HCM 2010 procedure was employed to calculate the approach delays of the roundabout. The same data set used as the input to the SIDRA software to simulate delays. To align the delay output with the actual conditions, a correlation equation was derived between the simulated and calculated delays for each approach and the intersection, as depicted in Table II and Fig. 2. Microsoft Excel tools were utilized for these correlation derivations.

It is important to note that a comprehensive analysis was conducted to determine the most suitable correlation between the simulated and calculated delays. The findings revealed that polynomial correlations outperformed linear correlations. These polynomial equations were capable of more accurately capturing the intricate relationships between the simulated and calculated delays, thus reflecting the complex dynamics of the intersection.

As discussed in Section 2, the required traffic volume and vehicle movement data were collected through video recording for approximately 5 h during the peak period. The maximum volumes for each approach within a 15-min are presented in Table I. The turning proportions for each approach movements were calculated using Corel studio software. The traffic volume of each approach road was utilized in the simulation for different scenarios and roundabout shapes, as presented in Table III. These volumes were subsequently assigned to the corresponding approaches within the proposed models to assess the operational performance of the roundabouts.

B. Effect of the Roundabout Geometric Shape

In this section, the effect of roundabout geometric shapes on the performance measures is examined by applying two test scenarios. In the first scenario, an identical traffic volume was assigned to each movement type, ensuring that the (LOS) of the roundabout remained above LOS F. Specifically, in a simulation case, 100% of capacity was used for each approach road. Subsequently, virtual volumes were allocated to the SW and NE approaches, while the SE and NW approaches were loaded with 75% of the maximum capacity. In the second scenario, the volumes assigned to the approaches were reversed. This approach is employed to investigate the impact of the short and long axes of the elliptical roundabout on traffic movement.

It is noteworthy that the utilization of values of 100% and 75%, both less than and greater than the roundabout's maximum capacity, contributes to a more comprehensive understanding of the LOS and the effects of geometric variations. This approach enables an evaluation of the roundabout's performance under different loading conditions and provides valuable insights into its behavior at various levels of congestion.

The results showed that there were evident differences in the performance parameters of the two models. The circular and elliptical roundabout were compared in terms of various performance measures, including delay, degree of saturation, travel speed, travel time, and others. Furthermore, the performance index of the elliptical roundabout was found to be 16.9% lower than that of the circular roundabout confirming its superior performance. Fig. 3 depicts the degree of saturation for each scenario implemented for both the circular (63 m dia.) and elliptical shapes.

TABLE II
SUMMARY OF THE DATA USED FOR THE CALIBRATION OF SIDRA SOFTWARE

Delay s/veh.					
Gate-1			Gate-3		
Calculated delay s/veh	Simulated delay s/veh	Calibrated delay s/veh	Calculated delay s/veh	Simulated delay s/veh	Calibrated delay s/veh
183.55	173.9	183.24	325.78	234.3	324.06
86.45	102.7	89.78	196.315	166.3	196.99
41.032	47.6	38.33	96.206	96.8	96.74
24.577	24.8	22.36	40.595	40.5	37.49
17.785	15.8	16.92	22.372	20.9	21.48
14.256	11.3	14.38	15.820	13.4	15.98
12.138	8.6	12.92	12.705	9.9	13.53
10.708	6.6	11.86	10.908	7.2	11.70
9.699	5.3	11.19	9.739	5.6	10.63

Gate-5			Gate-7			Intersection		
Calculated delay s/veh	Simulated delay s/veh	Calibrated delay s/veh	Calculated delay s/veh	Simulated delay s/veh	Calibrated delay s/veh	Calculated delay s/veh	Simulated delay s/veh	Calibrated delay s/veh
391.28	124.1	380.91	100.89	68	101.26	238.67	149.4	238.95
219.478	100.1	220.00	51.773	40	49.77	134.360	102.6	133.23
98.525	82.7	131.43	28.329	25.4	29.45	64.860	62.6	66.84
41.914	42.8	17.50	19.095	17.6	20.43	31.050	31.1	30.09
24.143	22.4	7.23	14.921	12.6	15.32	19.490	17.5	18.46
17.146	14.3	12.15	12.552	9.7	12.60	14.740	12	14.48
13.614	10.1	16.72	11.065	7.7	10.83	12.250	8.9	12.42
11.505	7.4	20.38	10.040	6.2	9.55	10.710	6.8	11.10
10.110	5.7	22.98	9.299	5.1	8.64	9.660	5.4	10.26

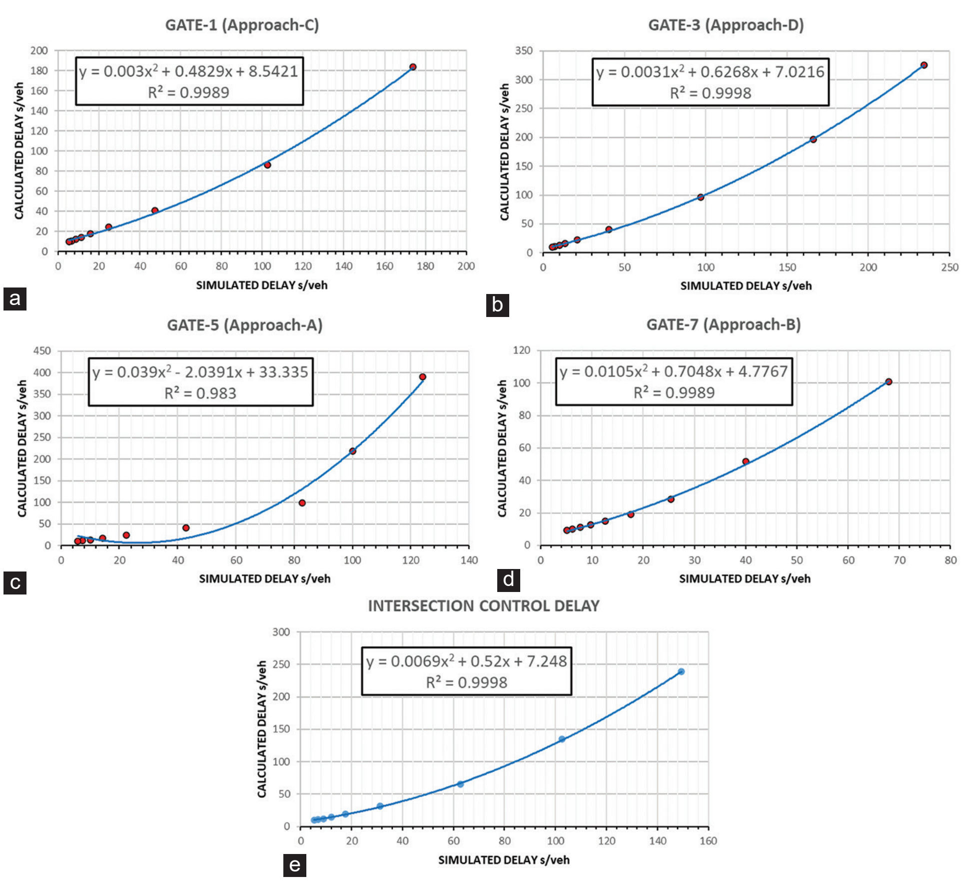

Fig. 2. Intersection control delay to perform calibration process (a) Gate 1 (approach-C). (b) Gate 3 (approach-D). (c) Gate 5 (approach-A). (d) Gate 7 (approach-B). (e) Intersection control delay.

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It should be noted that in the simulations, the approach speed and exit speed were set at 50 km/h. This decision was based on the data collected from video recordings and the posted speed limits at the roundabout approaches. However, it is important to highlight that the average travel speed, calculated by the software using input approach volumes and traffic composition, consistently remained below 50 km/h, with values ranging from 40 km/h to 45 km/h.

As depicted in the Fig. 3, at a low degree of saturation (<0.748), no changes in LOS were observed for both roundabout geometric shapes. However, at a higher degree of saturation (>0.748), the impact of changing approach volumes began to manifest in both roundabout geometric shapes, resulting in a decrease in LOS from A to B level. Further increments in the degree of saturation beyond 0.987 with the first scenario, tended to raise the LOS of the elliptical roundabout by one level compared to the circular one, while when the second scenario was applied both of them dropped to the next lower LOS.

In the last two simulations (11 and 12), the degree of saturations exceeded one for both scenarios 1 and 2. As illustrated in Fig. 3 in Scenario 1, the elliptical roundabout consistently outperforms the circular roundabout. However, in Scenario 2, both roundabouts experienced a drop to the next two lower LOS levels. This variation can be primarily attributed to two factors: (i) The circular roundabout, with a diameter of 63 m, necessitated vehicles to traverse a longer path compared to the elliptical roundabout, which featured major and minor axes of 63 m and 44 m, respectively; and (ii) the elliptical shape caused difficulty for some approach movement's turning maneuver while significantly facilitated the turning maneuver for others, as compared to the circular shape.

Furthermore, average control delay, which serves as the main indicator of LOS, was determined for each of the twelve-simulation test as shown in Fig. 4. The results indicate that the lower the demand, the less the difference between both roundabouts' performance in terms of control delay. However, as demand increased (especially on NW-SE approaches perpendicular to the major axis of the elliptical roundabout), this difference became more pronounced.

C. Effect of Heavy Vehicles

In this section, the effect of heavy vehicles on the roundabout performance is investigated through the application of two test scenarios presented in Section 3.2. It is important to note that for each scenario, four simulation tests were conducted with varying percentages of heavy vehicles, ranging from 2% to 12% as detailed in Table IV. These specific percentages were selected to assess the influence of traffic composition on the efficiency of both elliptical and circular roundabouts. In addition, these percentages were grouped into intervals, as displayed in Table IV, to evaluate the effects of varying heavy vehicle percentages on roundabout performance systematically.

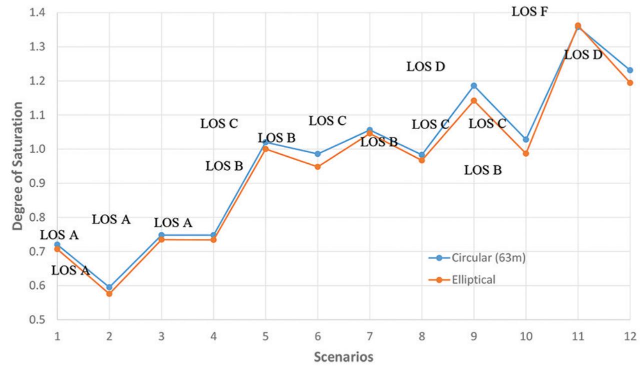

Fig. 3. Degree of saturation for different roundabout shape and loading configuration.

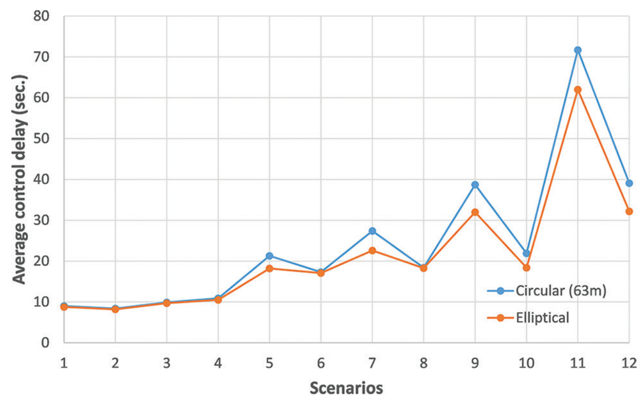

Fig. 4. Average control delay of both models with alternate approach volumes.

Furthermore, it should be emphasized that these percentage values closely approximate real-world data. By replicating the traffic compositions encountered in practical scenarios, insights can be gained into how varying proportions of heavy vehicles impact roundabout performance. Consequently, the utilization of these percentages serves a dual purpose: It reflects real-world conditions and allows for the analysis of roundabout performance under different traffic compositions.

The results showed that increasing the percentage of heavy vehicles from 2% to 5% tended to be inefficient in improving the LOS of the elliptical roundabout, while the LOS of the circular roundabout dropped from B to C level. At higher percentages of heavy vehicles, especially from 8% and 12%, the control delay increased by 28.9% and 35.2% for the elliptical and circular roundabouts, respectively, as demonstrated in Fig. 5. These results confirm that the performance of the elliptical roundabout consistently outperforms the circular roundabout under various scenarios. However, it is important to note that the elliptical roundabout was more susceptible to the changes in the percentage of heavy vehicles compared to the circular roundabout.

TABLE III
Loading configuration for different scenarios used in SIDRA

1						2					
Movement Volume veh/approach/15 min.				Approach	Volume Assignment	Movement Volume veh/approach/15 min.				Approach	Volume Assignment
U	L	R	TH			U	L	R	TH		
5	80	80	120	NE-SW	100%	8	90	90	130	NE-SW	100%
4	60	60	90	SE-NW	75%	6	68	68	98	SE-NW	75%
3						4					
5	80	80	120	SE-NW	100%	8	90	90	130	SE-NW	100%
4	60	60	90	NE-SW	75%	6	68	68	98	NE-SW	75%
5						6					
10	100	100	150	NE-SW	100%	12	115	115	125	NE-SW	100%
8	75	75	113	SE-NW	75%	9	87	87	94	SE-NW	75%
7						8					
10	100	100	150	SE-NW	100%	12	115	115	125	SE-NW	100%
8	75	75	113	NE-SW	75%	9	87	87	94	NE-SW	75%
9						10					
12	120	120	130	NE-SW	100%	12	120	120	150	NE-SW	100%
9	90	90	97	SE-NW	75%	11	98	98	113	SE-NW	75%
11						12					
12	120	120	130	SE-NW	100%	14	130	130	150	SE-NW	100%
9	90	90	97	NE-SW	75%	11	98	98	113	NE-SW	75%

TABLE IV
Alternate approach volume assignment for varying HV%

Applying uniform approach volume alternately with varying HV%					
Alternate approach volume with HV% assignment		Circular 63		Elliptical	
		Degree of saturation	LOS	Degree of saturation	LOS
1	C2 (2%) and E2 (2%)	0.999	B	0.995	B
2	C1 (2%) and E1 (2%)	0.972	B	0.951	B
3	C2 (5%) and E2 (5%)	1.065	C	1.02	B
4	C1 (5%) and E1 (5%)	1.008	C	0.972	B
5	C2 (8%) and E2 (8%)	1.146	D	1.099	C
6	C1 (8%) and E1 (8%)	1.008	C	0.984	B
7	C2 (12%) and E2 (12%)	1.232	E	1.217	D
8	C1 (12%) and E1 (12%)	1.13	C	1.072	C

C1-E1 : SW and NE Approaches 100% – SE and NW Approaches 75% of volumes assigned, C2-E2 : SW and NE Approaches 75% – SE and NW Approaches 100% of volumes assigned, LOS: Level of service

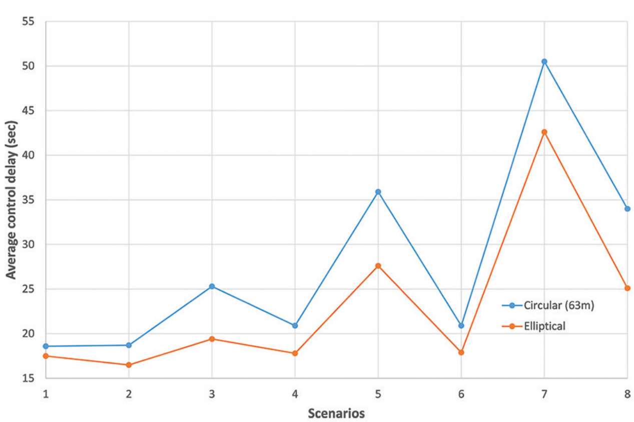

Fig. 5. Average control delay of C63m and elliptical models with alternate approach volumes for various percentage of heavy vehicles.

IV. Conclusion

In this study, two simulation models were developed using SIDRA Intersection software, featuring different geometric shapes of central islands: One with an elliptical shape and the other with a circular shape. The study assessed the operational performance of roundabouts, specifically comparing the delay and capacity of elliptical and circular geometric shapes. Various factors, including traffic volume, traffic composition, and degree of saturation, were considered. The investigation was initiated by assigning peak traffic volumes to both models, followed by the generation of twelve diverse scenarios. These scenarios encompassed gradual increases in lane volumes, spanning from levels of service A to F.

The results demonstrated that the elliptical roundabout exhibited superior operational performance compared to the circular roundabout, particularly in terms of capacity, LOS, and performance index parameters. The performance index of the elliptical roundabout was 16.9% lower than that of the circular roundabout, confirming its superior performance.

In addition, recognizing the importance of accommodating heavy vehicles in urban settings, a parametric study was conducted. It included eight simulation scenarios with varying heavy vehicle percentages (HV%). Results indicated at higher HV% levels, particularly around 8% and 12%, control delay increases by 28.9% and 35.2% for elliptical and circular roundabouts, confirming the elliptical roundabout's superior performance. However, it is crucial to highlight that the elliptical roundabout displayed higher susceptibility to increasing heavy vehicle percentages compared to the circular roundabout.

In conclusion, the findings suggest that the implementation of an elliptical central island can offer practical advantages and contribute to the enhanced performance of a roundabout. This trend becomes particularly prominent when the traffic volume along the approaches parallel to the longer axis of the elliptical roundabout surpasses the volume on the approach's perpendicular to this axis.

Moving forward, future research should explore specific design parameters and operational conditions contributing to elliptical central island advantages. In addition, a comprehensive study of traffic composition's impact on roundabout performance could provide valuable insights. Overall, this study underscores the potential benefits of adopting elliptical geometric shapes in certain traffic scenarios, calling for further research.

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