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Transportation Engineering Division
SCHOOL OF ENGINEERING, UNIVERSITY OF SEVILLE

FCTUC DEPARTAMENTO DE ENGENHARIA CIVIL
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE COIMBRA

Driver behavior characterization in roundabout crossings

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1. Background

Roundabouts are excellent alternative to traditional intersections:

- Increase of service levels;
- Increase of traffic flow;
- Increase of safety levels (reduction of the number of conflict points and the speed);
- Etc…

However, the influence of the roundabout geometry in the driver behavior is not very explicit.

This work aims to evaluate the driver behavior when crossing roundabouts, with detailed analysis before, during and after the roundabout crossing.

2. Methodological approach and site characterization

- An important arterial road in the city of Coimbra was selected;
- Road stretch with 3.6 km;
- 3 roundabouts to analyze the through movement;
- The distance between two consecutive roundabouts varies between 400 and 470 m;
- Grades below 2%;
- The speed limit is 50 km/h.

2. Methodological approach and site characterization

- 5 different drivers (2 females and 3 males) with more than 20 years of driver experience;
- Ages between 40 and 55;
- Two-way through movements in roundabouts 1, 2 and 3 were analyzed, leading to 6 cases studies;
- Each driver completed 5 laps under free flow conditions and no longer than 30 consecutive minutes.

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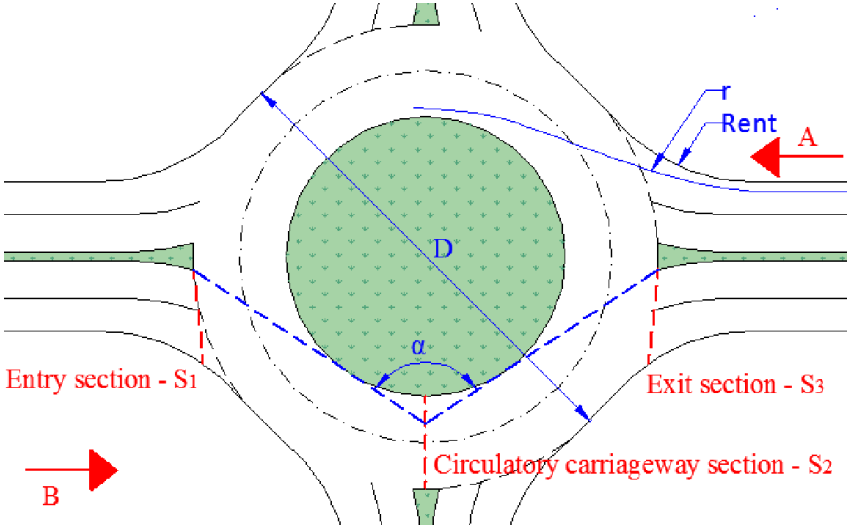
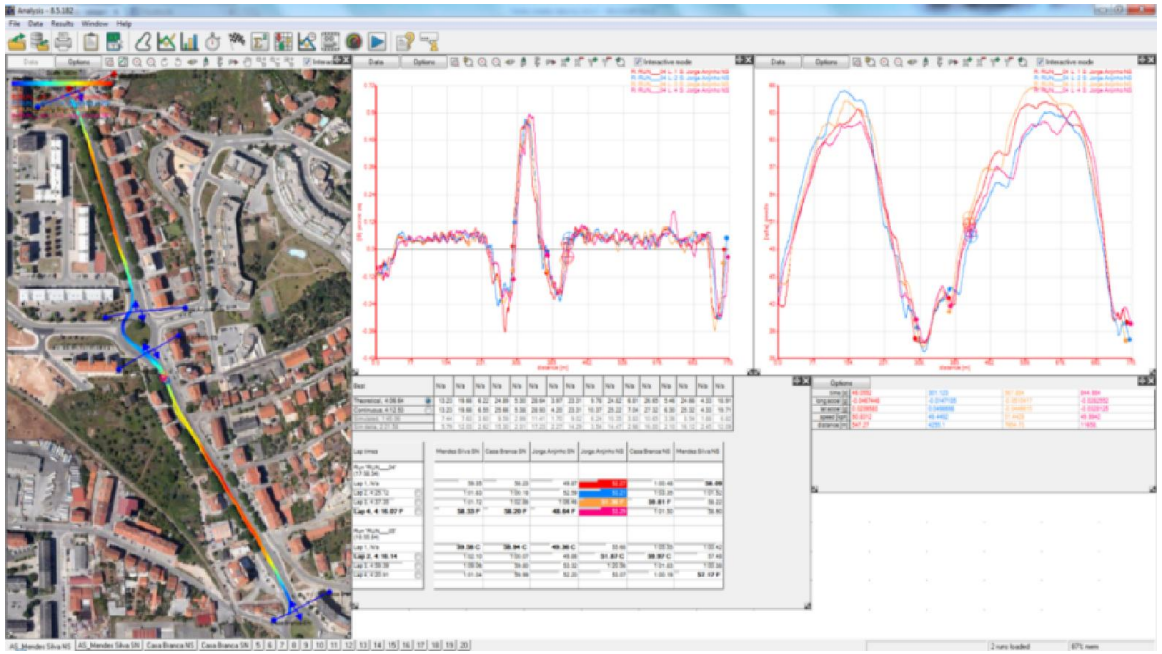
2. Methodological approach and site characterization



- The 3 roundabouts have different geometrical characteristics, but similar global dimensions;
- The driver behavior profile was characterized based on the following variables:
  - Influence zone;
  - Speed;
  - Lateral acceleration.

Roundabout	Direction	D (m)	α (º)	R_{ent} (m)	c=1/r (m^{-1})
1	A	64	155	45	0.000054
	B	64	104	21	0.000772
2	A	55	117	23	0.000149
	B	55	115	15	0.00178
3	A	59	103	33	0.000132
	B	59	155	33	0.000045

2. Methodological approach and site characterization



- Instrumented vehicle;
- Data logger;
- Race technology software (with maximum frequency of 20Hz)

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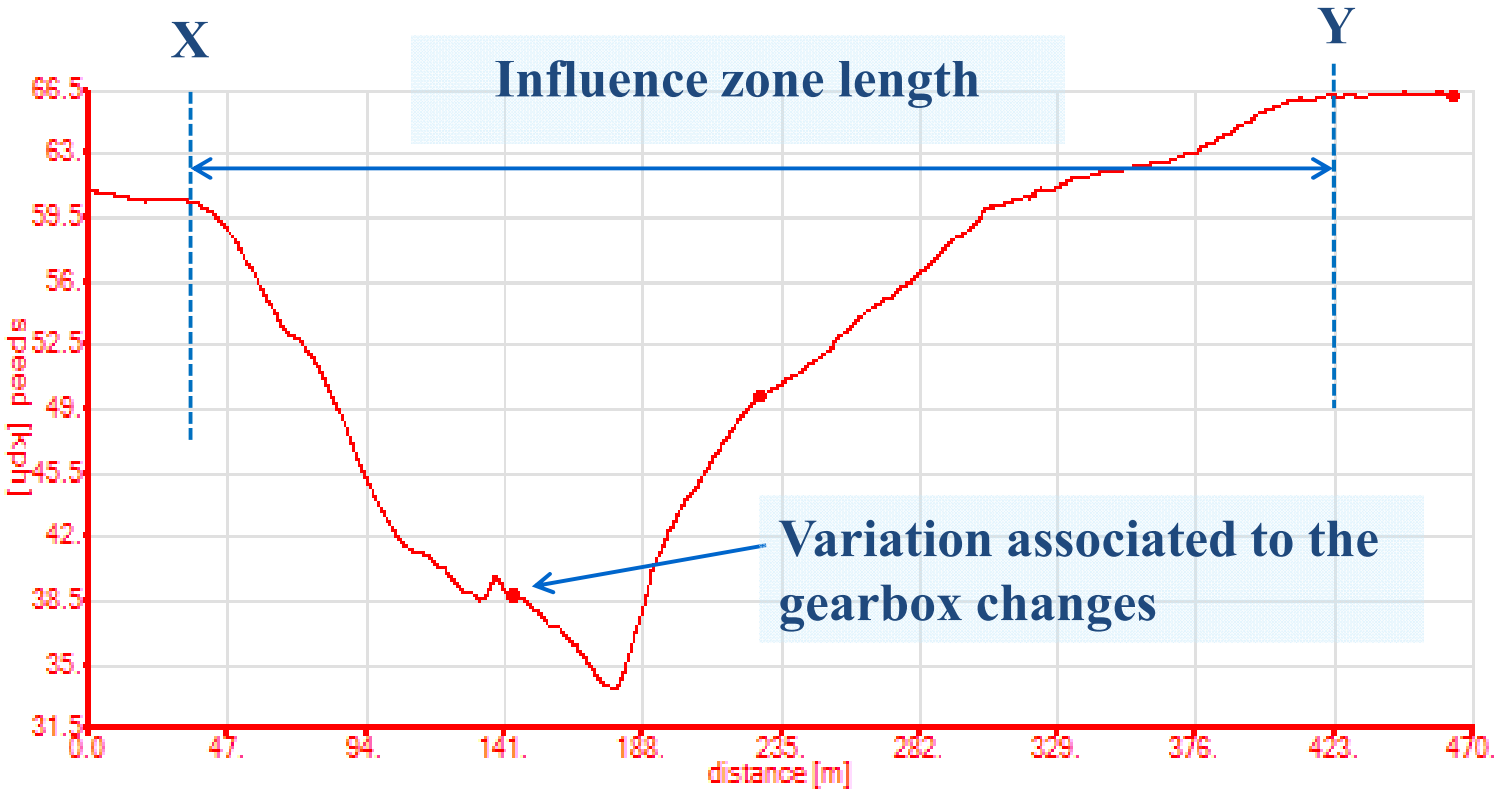
3. Results analysis

- The influence zone



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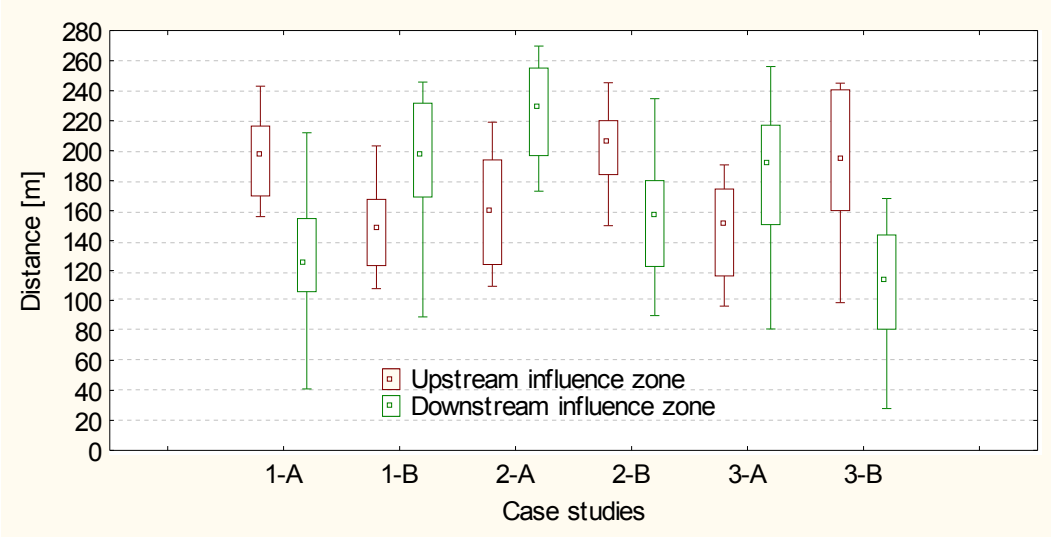
3. Results analysis

❑ The influence zone and approach speeds

- The analysis shows a significant variation in the influence zone's length;
- For each roundabout, the upstream and downstream values are very different;
- However, the average values for the global sample are very similar and close to 170 m;
- The approach speeds are presented in the table.



Case studies	Approach speed (km/h)		
	Average speed	P15	P85
1-A	70.9	64.6	76.5
1-B	68.3	61.3	74.8
2-A	64.5	58.3	71.5
2-B	71.8	66.9	74.8
3-A	62.7	57.5	67.5
3-B	66.3	60.2	71.4

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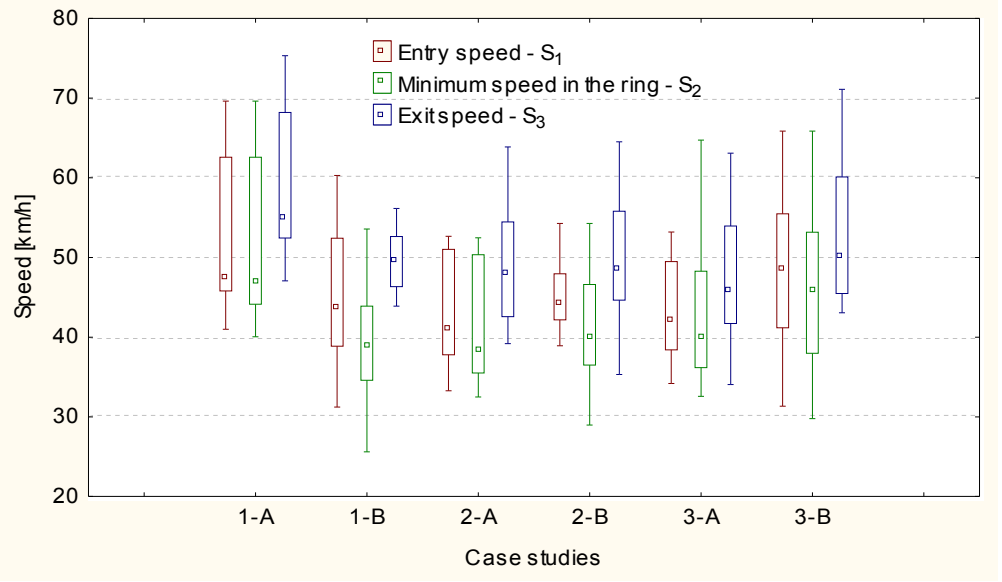
3. Results analysis

- **Speeds in the sections S1 (entry), S2 (ring) and S3 (exit)**

- The results show some variation in the average speed for each case study and section under study;
- The average speed in the entry is about 45 km/h;
- The average speed in the exit is near 50 km/h;
- As expected, the minimum speed is achieved in the ring.



ID	Entry speed – S_1 (km/h)		Minimum speed in the ring – S_2 (km/h)		Exit speed – S_3 (km/h)	
	Average speed	σ	Average speed	σ	Average speed	σ
1-A	50.41	7.75	49.98	7.82	57.38	7.29
1-B	44.86	7.08	39.57	6.52	49.42	2.92
2-A	41.96	5.09	39.92	5.46	48.15	6.04
2-B	45.08	3.88	41.26	5.94	50.15	6.66
3-A	42.55	4.72	40.98	6.51	46.98	5.93
3-B	49.06	7.87	47.44	8.37	52.68	7.52
Average	**45.65**	**6.07**	**43.19**	**6.77**	**50.79**	**6.06**

3. Results analysis

❑ ANOVA and t-student test

a) Some dispersion, in a balanced way, with particular relevance in the intra-driver variation;

b) The effect of the chosen entry lane are only statistically significant for the entry speed (p-value<0.05).

		Entry speed (S_1)	Minimum speed in the ring (S_2)	Exit speed (S_3)
ANOVA	Factor (driver) SS	4102.2	5473.8	4128.3
	Error	4388.2	5435.5	4732.8
	Factor Degrees of freedom	4	4	4
	Factor – MS	1025.5	1368.4	1032.1
	Factor – F	40.90	44.06	38.16
	p-value	0.0000	0.0000	0.0000
T-student test	Average for the right lane	44.2833	42.4474	49.6383
	Average for the left lane	46.5516	43.5424	51.6136
	σ for right lane	5.9387	7.1138	6.4425
	σ for left lane	7.4922	8.3699	7.4277
	t-value	-2.2288	-0.9385	-1.8926
	p-value	0.0271	0.3492	0.0600

3. Results analysis

❑ Lateral acceleration

- Lateral accelerations was used in order to evaluate the discomfort level accepted by each driver to cross the roundabout.
- Two indicators were used:
  a) Lateral acceleration at the entry
  b) Lateral acceleration at the exit.

Difference between the maximum lateral acceleration immediately before the entry and the maximum value achieved in the ring.

Difference between the maximum lateral acceleration achieved in the ring and the value immediately after the exit.

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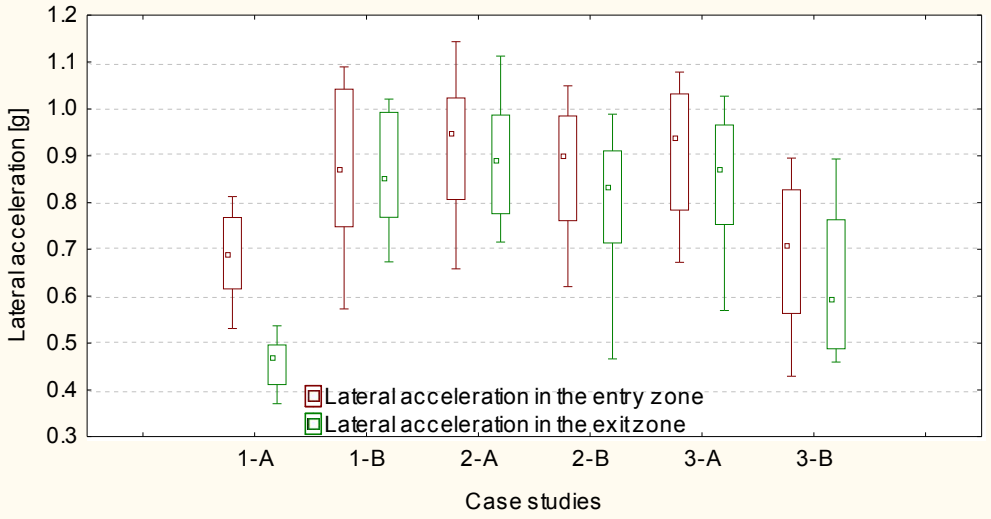
3. Results analysis

❑ Lateral acceleration

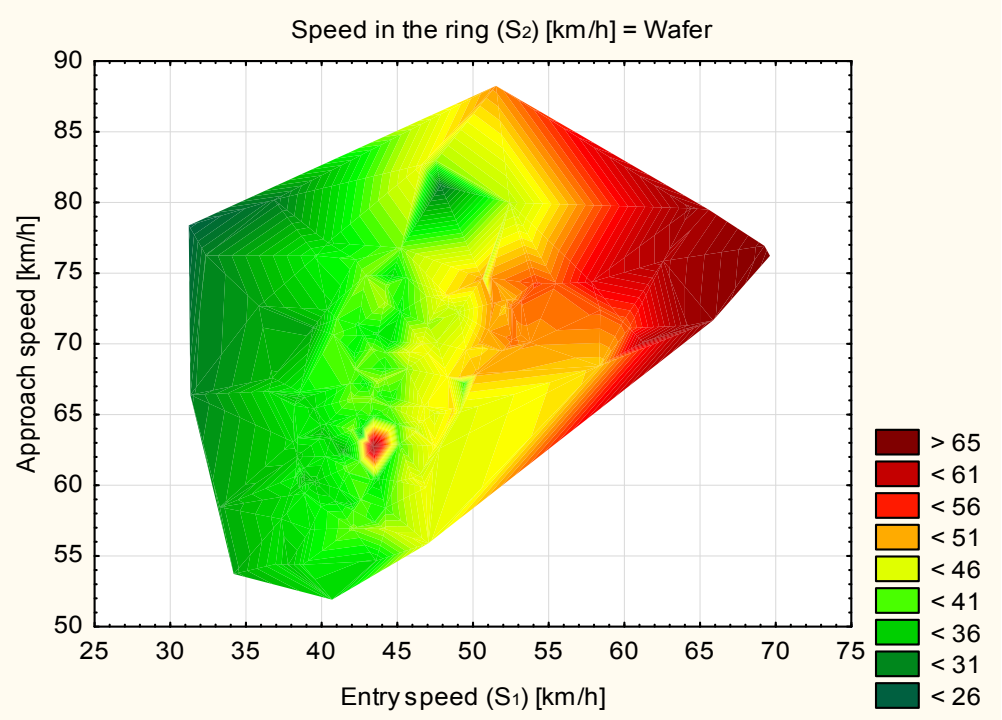
- Excepting the 1-A and 3-B, the values tend to be similar, although they are associated to high dispersion levels.
- The average of the amplitude values is about 0.83g, which means a high discomfort level accepted by drivers during the roundabout crossings.
- There is a higher discomfort level at the entry than at the exit zone, despite the higher exit speed.



Case studies	Maximum lateral acceleration in the ring *(g)*			
	Average	P_{15}	P_{85}	Máx.
1-A	0.43	0.38	0.47	0.50
1-B	0.52	0.46	0.61	0.64
2-A	0.57	0.50	0.62	0.66
2-B	0.53	0.50	0.64	0.71
3-A	0.60	0.53	0.68	0.72
3-B	0.44	0.37	0.50	0.56
Global	**0.52**	**0.42**	**0.62**	**0.72**

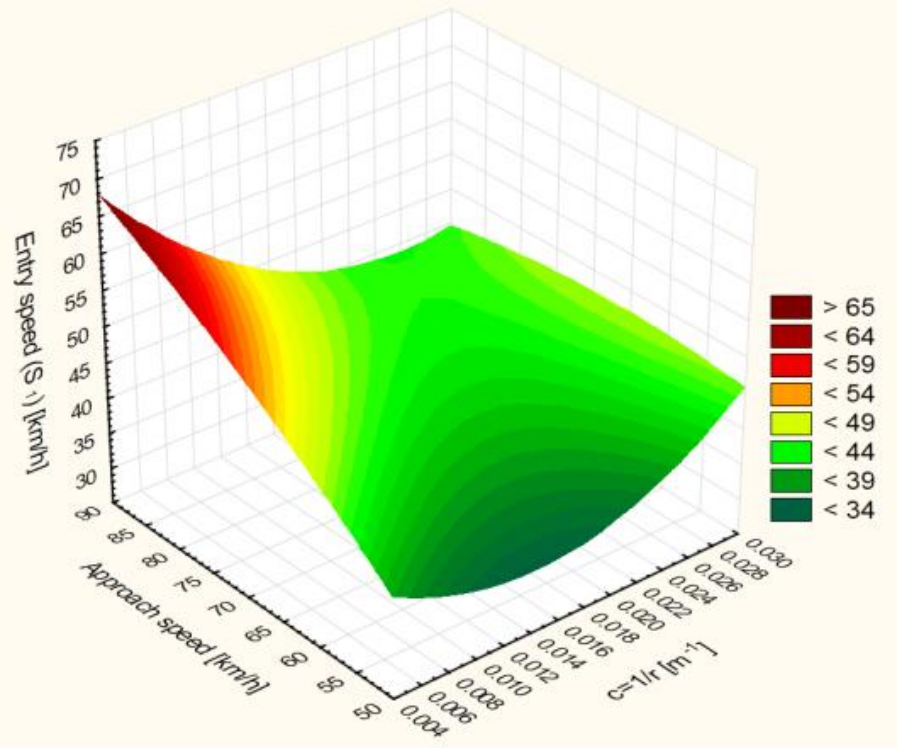
4. Influence of kinematic/behavioral and geometric variables – Single/multiple regression analysis

- As expected, a positive correlation was identified between the entry and approach speeds, as well as the speed in the ring;
- It was also evident that the behavior observed at the entry usually determines the drivers' behavior during the crossing and at the exit of the roundabout.



4. Influence of kinematic/behavioral and geometric variables – Single/multiple regression analysis

- A positive correlation between the approach speed, entry speed (S_1) and the curvature degree ($c=1/r$);



4. Influence of kinematic/behavioral and geometric variables – Single/multiple regression analysis

Variable	Upstream influence zone length – R^2= 0.4716				Entry speed – R^2= 0.5603			
	b	Std. Error	t	p-value	b	Std. Error	t	p-value
Intercept	-523	117.28	-4.45683	0.000015	26.42	4.426	5.96861	0.00000
Approach speed	1.00	0.34	3.04968	0.002649	0.42	0.053	7.94857	0.00000
Rent	-6.00	1.02	-5.64805	0.00000	Not significant			
Lateral acceleration in the entry	Not significant				46.98	5.322	8.82791	0.00000
1/r²	-219368	41880.13	-5.23801	0.000000	77296.63	9038.665	8.55177	0.00000
c=1/r	Not significant				-3109.46	332.068	-9.36392	0.00000
D	13.00	2.88	4.56848	0.000009	Not significant			
α	0.00	0.16	2.96148	0.003489	Not significant			

Conclusions and future work

- In spite of the stretch under analysis being under a legal maximum speed limit of 50 km/h, approach speeds of 70 km/h were observed;
- Roundabouts are efficient traffic calming measures, with speed reductions between 26% and 37% were measured;
- However the roundabout's ability to enforce homogenous driver behaviors wasn't so clear. This could be related to the double-lane roundabouts, which give a higher freedom of movement;
- This work illustrated a significant intra-driver behavior variability (ANOVA);
- The total length of the roundabout influence zone is between 400 and 500 meters. The regression analysis shows that this variable depends on the approach speed and the deflection level of the roundabout;

Conclusions and future work

- The relation between the approach and the entry speeds was confirmed, identifying the approach speed, the lateral acceleration variation and the curvature degree as statistically significant;
- For future work, it seems important to study a larger sample of sites and drivers;
- It seems also important to include the shortest path trajectories in the analysis, which having higher speeds in the three sections under analysis (S1, S2 and S3) could provide another perspective for the performance assessment of roundabouts.

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Thank You

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