Turbo roundabouts: geometric design parameters and performance analysis

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Abstract - **A turbo roundabout is a particular type of roundabout where entering and circulating lanes are bounded by traffic signs and by non-mountable curbs. The physical separation between lanes, both at entries and on the ring, helps to prevent side collisions crossing the roundabout.**

The main advantages of turbo roundabouts are: *i)* reduction in the number of potential conflict points; *ii)* lower speed of vehicles passing through the intersection; *iii)* safety conditions at the intersection due to lower risk of side-by-side accidents. Also, in some cases the capacities of turbo roundabouts are higher than the capacities of conventional roundabouts.

This paper presents an estimation of capacity, delays and level of service of turbo roundabouts in undersaturation conditions, considering both vehicular flow and pedestrian stream. It also examines the geometric parameters of the central island and circulating lanes in several turbo roundabout layouts.

I. INTRODUCTION

A turbo roundabout is a particular type of roundabout where all lanes are bounded by traffic signs and by non-mountable curbs installed at entering and circulating lanes. Turbo roundabouts also have a very particular shape to accomplish the splitting of traffic streams and to prevent cars weaving through. As a result of the lane dividers, turbo roundabouts force circulating traffic flows to spiral trajectories; each entering lane is therefore specialized in a single turning maneuver and drivers have to choose their direction before they enter the intersection and the appropriate lane on the circulatory roadway.

In particular, turbo-roundabouts are characterized by the following features:

a) entry lanes are specialized for turning manoeuvres, physically bounded by curbs;
b) users who are going to get onto the intersection have to select the lane along the entry arm in order to make their manoeuvre (through and left movements, right turnings);
c) after choosing their own lane, their path is partially constrained by the presence of curbs installed along the circulatory roadway up to the exit;
d) all the vehicles coming from the entries, even if they follow different behavioural patterns, have to give priority to circulating vehicles;
e) through movements and left-turn manoeuvres come into conflict with circulating vehicles which are along one or two lanes and need to be passed through, so that entering vehicles can get onto the appropriate circulating lane (i.e. the inner lane at the circulatory roadway). In this case, unless the conflicting vehicles are forced to stop, entering vehicles have to wait for the joint probability to find gaps wide enough (i.e. above the critical gap) between vehicles distributed along the circulatory roadway in parallel lines;
f) unlike the above, the right-turn manoeuvres occur in the same way as at traditional roundabouts.

If compared with conventional roundabouts, the main benefits of a turbo roundabout are [1], [2]:

- lower number of potential conflict points between vehicles; for example, a four-arm turbo roundabout is characterized by ten conflict points, whereas a two-lane roundabout has twenty-two (see Table 1);
- slower speed along the ring;
- lower risk of side-by-side accidents.

In light of these considerations, turbo roundabouts could be an alternative to two-lane roundabouts, especially to guarantee a high safety level, for example in case of quite heavy cyclist/pedestrian traffic.

TABLE I

NUMBER OF CONFLICT POINT

Number of arms	Unsignalized intersection	Two-lane roundabout	Turbo roundabout
3	9	16	7
4	32	22	10

Fig. 1. Pictures of turbo roundabouts

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II. Geometric Characteristics

The characteristic shape of the central island and circulating lane (see Figure 2) is generally designed through arcs of circumferences with different centers and radii. The geometric design follows these subsequent steps:

1) to single out the center of the intersection (or the intersection point among crossing roads);
2) to select the width of the lane and the semi-width of the safety island among lanes (curb and shoulder), whose sum corresponds to the distance from C_1 to C_2: $\overline{C_1C_2} = \overline{\Delta R}$;
3) to position C_1 and C_2 centers symmetrically as to the intersection point among the road axes;
   4) to fix the value of the first radius and put $R_1 = R_4$; the other radius values are defined by the relation (see Figure 2): $R_i = R_{i-1} + \Delta R$

The radius sizes of a roundabout with the spiral course of the circulatory carriageway and the width of the circulatory traffic lane must be selected in a way that the driving speed through the intersection does not exceed or equals 40 km/h [3]. Table 2 shows the radius sizes (R_1, R_2, R_3, R_4, R_5, R_6) for mini, standard, medium and large turbo roundabouts.

$$\begin{cases} R_3 = R_2 + \Delta R \\ R_2 = R_1 + \Delta R \\ R_6 = R_5 + \Delta R \\ R_5 = R_4 + \Delta R \end{cases}$$

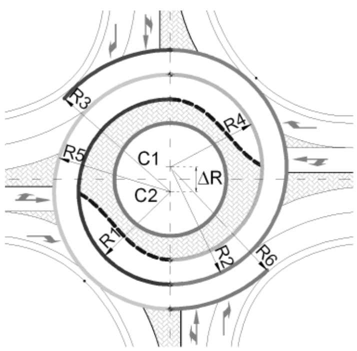

Fig. 2. Geometric design of a turbo roundabout

TABLE II
RADIUS SIZES OF TURBO ROUNDABOUTS

ELEMENT	MINI	STANDARD	MEDIUM	LARGE
ΔR = 4.20 m (Lane width = 3.50 m)				
R₁ [m]	10.50	12.00	15.00	20.00
R₂ [m]	14.70	16.20	19.20	24.20
R₃ [m]	18.90	20.40	23.40	28.40
R₄ [m]	10.50	12.00	15.00	20.00
R₅ [m]	14.70	16.20	19.20	24.20
R₆ [m]	18.90	20.40	23.40	28.40
ΔR = 4.45 m (Lane width = 3.75 m)				
R₁ [m]	10.50	12.00	15.00	20.00
R₂ [m]	14.95	16.45	19.45	24.45
R₃ [m]	19.40	20.90	23.90	28.90
R₄ [m]	10.50	12.00	15.00	20.00
R₅ [m]	14.95	16.45	19.45	24.45
R₆ [m]	19.40	20.90	23.90	28.90
ΔR = 4.70 m (Lane width = 4.00 m)				
R₁ [m]	10.50	12.00	15.00	20.00
R₂ [m]	15.20	16.70	19.70	24.70
R₃ [m]	19.90	21.40	24.40	29.40
R₄ [m]	10.50	12.00	15.00	20.00
R₅ [m]	15.20	16.70	19.70	24.70
R₆ [m]	19.90	21.40	24.40	29.40

If the above design has an undoubted advantage of being geometrically simple, it has some disadvantages for being developed through circle arcs, for instance:

1) theoretically, it determines an instantaneous variation of the centrifugal acceleration near the discontinuity in the curvature of ring lanes. The value of such variation is equal to:

$$\Delta a_t = \frac{v_i^2 \cdot R_{i+1} - v_{i+1}^2 \cdot R_i}{R_i \cdot R_{i+1}} \quad (1)$$

where:

- Δa_t = variation of the centrifugal acceleration;
- R_i = i-th curvature radius;
- R_{i+1} = curvature radius following R_i;
- v_i = running speed on the lane with a radius R_i;
- v_{i+1} = running speed on the lane with a radius R_{i+1}.

If we assume a constant running speed along ring lanes, the variation of the centrifugal acceleration can be evaluated as follows:

$$\Delta a_t = \frac{v^2 \cdot (R_{i+1} - R_i)}{R_{i+1} \cdot R_i} \quad (2)$$

2) it involves sudden modifications in the vehicle steering maneuver.

For these reasons, in designing a turbo roundabout with a continuous variation of curvature in circulating lanes, spiral turns can sometimes be applied [4].

As the width of circulating lanes has to be kept constant along their development, it follows that the curve has to be marked by a constant step equal to the transversal spacing between the lanes. The last characteristic belongs to the Archimedean spiral (see Figure 3), whose equation is the following:

$$R = a \cdot \theta \quad (3)$$

where R is the radial distance from the origin, a is the parameter of the curve and θ is the polar angle (i.e. the angle corresponding to the point with curvature 1/R).

The Archimedean spiral represents the trajectory of a point P moving with a constant speed along a half-line pivoting with constant speed on the point O. Any half-line originating from the point O (i.e. the origin of a system of Cartesian axes) intercepts equal segments on the Archimedean spiral:

$\overline{OA} = \overline{AB} = \overline{BC} = \ldots$

The well-known parametric equations of the spiral are as follows:

$$x = R \cdot \cos\theta = a \cdot \theta \cdot \cos\theta \quad (4)$$

$$y = R \cdot sen\theta = a \cdot \theta \cdot sen\theta \quad (5)$$

In order to determine the step of the spiral K, denoting with n a natural number (n = 1,2,3,…), the following conditions should be assumed:

$$R_n = a \cdot \theta_n \quad (6)$$

$$R_{n+1} = a \cdot \theta_{n+1} \quad (7)$$

$$K = R_{(n+1)} - R_n = a \cdot (\theta_{n+1} - \theta_n) = 2\pi \cdot a \quad (8)$$

The value of the a parameter can be obtained from these relations, on condition that the step K of the spiral is known:

$$a = \frac{K}{2\pi} \quad (9)$$

The length of the spiral can be obtained from the following equation:

$$L = \frac{1}{2} \cdot a \cdot \left[\theta \cdot \sqrt{1+\theta^2} + \ln\left(\theta + \sqrt{1+\theta^2}\right)\right] \quad (10)$$

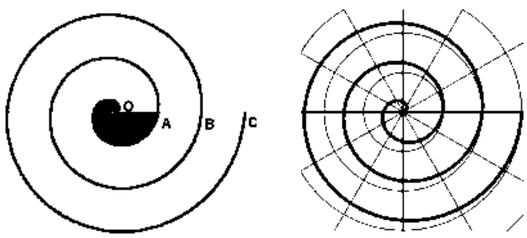

Fig. 3. The Archimedean spiral

Entry and exit radii: radii entering and exiting turbo roundabouts can be evaluated by means of the same values as those employed in conventional roundabouts, that is:

- minimum entry radius, $R_{e,\,min}$ = 12.00 m;
- minimum exit radius, $R_{u,\,min}$ = 15.00 m.

Moreover, in order to favor entry and exit maneuvers, the lanes should be as wide as 4.00 m and as 4.50 m, entering and exiting a roundabout respectively.

Fig. 4. Details of entry and ring lanes [3]

III. MODELS FOR THE CALCULATION OF THE CAPACITY

The main theoretical and experimental models specifically designed for the performance analysis of turbo roundabouts are those by Fortuijn [5] and by Giuffrè, Guerrieri, Granà [1], [6]. These models are associated to Brilon's, specially adapted to turbo designs and already implemented in the specialized software Kreisel 7.0.

A. Model n. 1 (Fortujn): its strength lies in separately calculating the capacity values of entry lanes and in considering the effect of "pseudo-conflicts" but it does not allow to evaluate entry capacities (simple capacity). The right-turn lane capacity C_{Er} and the left-turn lane capacity C_{El} are obtained from the following expressions:

$$C_{El} = C_0 - b_{\min} \cdot Q_{R\min} - b_{\max} \cdot Q_{R\max} - a_1 \cdot Q_S \quad (11)$$

$$C_{Er} = C_0 - b_u \cdot Q_{Ru} - a_r \cdot Q_S \quad (12)$$

where:

- C_0 = capacity with no circulating flow [pcu/h];
- Q_R = circulating traffic volume [pcu/h];
- Q_S = exit traffic volume [pcu/h];
- a_l, a_r, bu, b_{max}, b_{min} = coefficients dependent on the intersection-based geometry.

The subscripts l, r, I, U, R_{min} and R_{max} denote:

- l = lane for left-turning traffic (and for intersection-crossing maneuver);
- r = right-turn lane;
- I = inner lane of the roundabout;
- U = outer lane of the roundabout;
- R_{min} = ring lane with the lowest traffic volume;
- R_{max} = ring lane with the highest traffic volume.

B. Model n. 2 (Giuffrè, Guerrieri, Granà): In order to calculate the capacity of northbound and southbound approaches, i.e. the minor road (see Figure 2), the right-turn lane capacity ($C_{E,R}$) and the through and left-turn lane capacity ($C_{E,TLT}$) should be worked out separately by applying the following two equations [1], [6]:

$$C_{E,R} = 3600 \cdot (1 - \frac{T_{\min} \cdot Q_{c,e}}{3600}) \cdot \frac{1}{T_f} \cdot e^{-\frac{Qc,e}{3600} \cdot (T_g - \frac{T_f}{2} - T_{\min})} \quad (13)$$

$$C_{E,TLT} = 3600 \cdot [1 - \frac{T_{\min} \cdot (Q_{c,e} + Q_{c,i})}{3600}] \cdot \frac{1}{T_f^{'}} \cdot e^{-\frac{Qc,e+Qc,i}{3600} \cdot (T_g^{'} - \frac{T_f^{'}}{2} - T_{\min})} \quad (14)$$

where:

$C_{E,R}$ = right-turn lane capacity at the entry E [veh/h];

$C_{E,TLT}$ = through and left-turn lane capacity at the entry E [veh/h];

$Q_{c,e}$ = circulating traffic flow in the outer ring lane opposite the entry E [veh/h];

$Q_{c,i}$ = circulating traffic flow in the inner ring lane opposite the entry E [veh/h];

T_g, $T_g^{'}$ = critical gap [s], (the values are different for the two entry lanes);

T_f, $T_f^{'}$ = follow – up time [s] (the values are different for the two entry lanes);

T_{min} = the shortest headway time between vehicles moving along the circulating lanes [s].

Each entry lane at a turbo roundabout is characterized not only by different capacity values (C_i), but also by a different flow rate (Q_i); it results that the degree-of-saturation ($x_i = Q_i/C_i$) can differ between lanes of the same entry and then the total entry capacity is not a simple sum of the single lane capacities. For these reasons the effective entry capacity C_E can be obtained from the following equations:

$$X = \max\left(\frac{Q_i}{C_i}\right) = \max(x_i) \quad i = 1,2 \quad (15)$$

$$\rho_i = \frac{x_i}{X} \quad (16)$$

$$C_E = \sum_{i=1}^{n} \rho_i \cdot C_i = \frac{\sum_{i=1}^{n} Q_i}{X} \quad (17)$$

$$C_E = \frac{(Q_{E,R} + Q_{E,TLT})}{\max[\frac{Q_{E,R}}{C_{E,R}}, \frac{Q_{E,TLT}}{C_{E,TLT}}]} \quad (18)$$

x_i = degree-of-saturation at the lane i (demand flow rate/capacity ratio);
X = degree-of-saturation at the critical lane (lane marked by the highest demand/capacity ratio between the examined lanes);
ρi = utilization ratio at the lane i;
$Q_{E,R}$ = demand flow rate of the right-turn lane at the entry E;
$Q_{E,LTL}$ = demand flow rate of the through and left-turn lane at the entry E.

The following Figure 5 exemplifies the variation of entry capacities as a function of the utilization degree at lanes under given boundary conditions. The surface in Figure 5 has been developed through balanced flows at circulating lanes: $Q_{c,i}$ = $Q_{c,e}$ = 500 veh/h; the right-turn lane capacity is $C_{E,R}$ = 1127 veh/h; the through and left-turn lane capacity is $C_{E,TLT}$ = 671 veh/h.

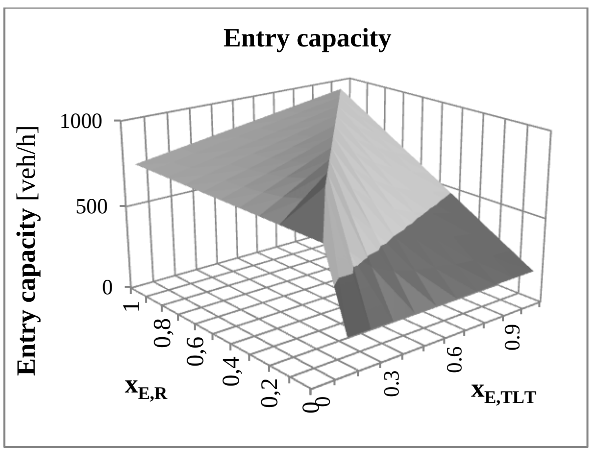

Fig. 5. Entry capacity

IV. The Effect Of Pedestrian Flows

The analysis of the effect of pedestrians flow on the capacity at entry of turbo-roundabouts, according to the German method [7], can be obtained as following:

$$C_{E,R}^{\ ped} = C_{E,R} \cdot M_{E,R} \quad (19)$$

$$C_{E,TLT}^{\ ped} = C_{E,TLT} \cdot M_{E,TLT} \quad (20)$$

$$M_{E,R} = (1119{,}5 - 0{,}715 \cdot Q_{c,e} - 0{,}644 \cdot Q_{ped} + 0{,}00073 \cdot Q_{c,e} \cdot Q_{ped}) / (1069 - 0{,}65 \cdot Q) \quad (21)$$

$$M_{E,TLT} = [1119{,}5 - 0{,}715 \cdot (Q_{c,e} + Q_{c,i}) - 0{,}644 \cdot Q_{ped} + 0{,}00073 \cdot (Q_{c,e} + Q_{c,i}) \cdot Q_{ped}] / [1069 - 0{,}65 \cdot (Q_{c,e} + Q_{c,i})] \quad (22)$$

$$C_E^{\ ped} = \frac{(Q_{E,R} + Q_{E,TLT})}{\max[\frac{Q_{E,R}}{C_{E,R}^{\ ped}}, \frac{Q_{E,TLT}}{C_{E,TLT}^{\ ped}}]} \quad (23)$$

where:
$M_{E,R}^{\ ped}$ = right-turn lane pedestrian capacity reduction factor;
$M_{E,TLT}^{\ ped}$ = through and left-turn lane pedestrian capacity reduction factor;
$C_{E,R}^{\ ped}$ = right-turn lane vehicle capacity considering impact of pedestrians [veh/h];
$C_{E,TLT}^{\ ped}$ = through and left-turn lane vehicle capacity considering impact of pedestrians [veh/h];
$C_{E,R}$ = right-turn lane vehicle capacity (no pedestrians crossing only vehicles) [veh/h];
$C_{E,TLT}$ = through and left-turn lane vehicle capacity (no pedestrians crossing only vehicles) [veh/h];
$C_E^{\ ped}$ = entry capacity considering impact of pedestrians [veh/h].

V. Estimation Od Delay And Level Of Service

After calculating the capacity and degree of saturation of each lane, in case of pedestrian flow, mean control delay can be determined from the following equation [8]:

$$D_{E,R}^{\ ped} = \frac{3600}{C_{E,R}^{\ ped}} + 900 \cdot T \cdot \left[\frac{Q_{E,R}}{C_{E,R}^{\ ped}} - 1 + \sqrt{(\frac{Q_{E,R}}{C_{E,R}^{\ ped}} - 1)^2 + \frac{(\frac{3600}{C_{E,R}^{\ ped}}) \cdot (\frac{Q_{E,R}}{C_{E,R}^{\ ped}})}{450 \cdot T}} \right] + 5 \quad (24)$$

$$D_{E,TLT}^{\ ped} = \frac{3600}{C_{E,TLT}^{\ ped}} + 900 \cdot T \cdot \left[\frac{Q_{E,TLT}}{C_{E,TLT}^{\ ped}} - 1 + \sqrt{(\frac{Q_{E,TLT}}{C_{E,TLT}^{\ ped}} - 1)^2 + \frac{(\frac{3600}{C_{E,TLT}^{\ ped}}) \cdot (\frac{Q_{E,TLT}}{C_{E,TLT}^{\ ped}})}{450 \cdot T}} \right] + 5 \quad (25)$$

where for the lane i: Di = mean delay for the single vehicle queuing at entry; Qi = flow rate (veh/h); Ci = capacity (veh/h); T = reference time (h).

In order to define the level of service at each entry lane, in absence of experimental data, valid indications for unsignalized intersections can be given by HCM 2000, chapter 17, [8] (see table 3).

TABLE III
Level of service

LEVEL OF SERVICE	D_E (mean delay)
A	0 ÷ 10 (sec/veh)
B	10 ÷ 15 (sec/veh)
C	15 ÷ 25 (sec/veh)
D	25 ÷ 35 (sec/veh)
E	35 ÷ 50 (sec/veh)
F	> 50 (sec/veh)

Generally speaking, delays will differ at the two entry lanes; so the level of service of the right-turn lane needs to be differentiated from the corresponding level of service at the through and left-turn lane. Should global information be necessary, however, the determination of the mean of delays at each lane can still be of help; an overall average delay can be obtained by giving different weights to these values according to their respective traffic demand. For instance, the performances at a conventional intersection can be compared with those at a turbo-roundabout, but the latter requires a detailed evaluation at each lane. The global mean delay at entry D_E is expressed by the following equation:

$$D_E = \frac{D_{E,R}{}^{ped} \cdot Q_{E,R} + D_{E,TLT}{}^{ped} \cdot Q_{E,TLT}}{Q_{E,R} + Q_{E,TLT}} \quad (27)$$

where $D_{E,R}{}^{ped}$, $Q_{E,R}$, $D_{E,TLT}{}^{ped}$, $Q_{E,TLT}$ are respectively delays and flow rates at the two lanes of the entry E. Figure 6 shows an example of the global delay variation at entry in relation to the degree of saturation at each lane (no pedestrian flow).

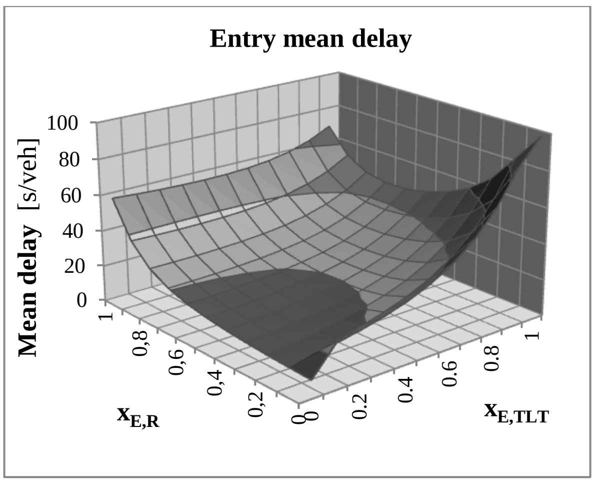

Fig. 6. Entry mean delay (no pedestrian flow)

Figure 7 exemplifies the variation of entry mean delay as a function of the entry total flow and pedestrian stream (100 ped/h, 500 ped/h and 1000 ped/h) under given boundary conditions.

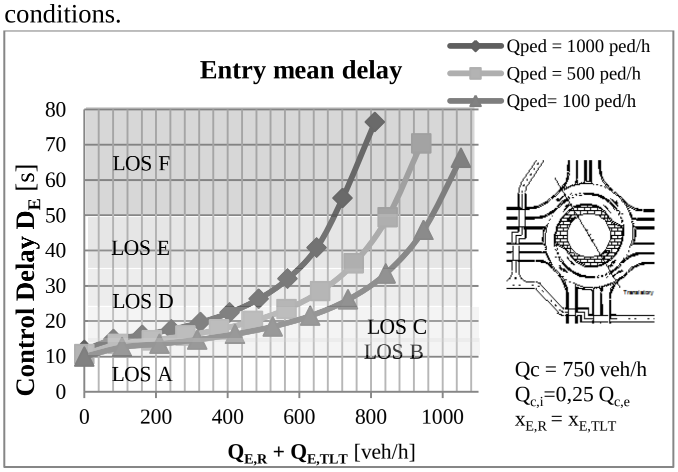

Fig. 7. Entry mean delay as a function of the entry total flow and pedestrian stream

VI. CONCLUSIONS

Roundabouts with turbo geometric design (turbo roundabouts) provide potentially better safety conditions than similar conventional geometric designs, thanks to the specific configuration of the central island and the ring lanes and to the physical separation of the traffic lanes. The give way regime and the maneuvering performances at intersections do not allow to apply the functional analysis models normally employed in conventional intersections to turbo roundabouts

As a matter of fact, the calculation of the simple entry capacity can be done only after determining the capacity of the single traffic lanes which form the entry ("lane by lane" analysis).

This paper deals with the main geometric characteristics of turbo roundabouts, suggesting the procedures to design the central island (configuration with "circle arcs" and "spiral"), the traffic lanes and the radii at each entry and exit of the intersections. It moreover describes the most recent models to calculate the capacity at entries and to determine the performances of turbo roundabouts in terms of vehicle delays and levels of service. The capacity at each entry of a turbo-roundabout has been shown to be conditioned by the capacity at single lanes, by conflicting vehicles and pedestrian flow, by the combination of circulating flows along lanes at circulatory carriageway (in case of North and South entries), by user behaviours (through parameters T_g, T_f, T_{min}) as well as by the balance of traffic demand at the entry.

Contrary to models for conventional roundabouts, at entries of turbo-roundabouts there is no biunique relation between circulating flow and entry capacity but only a continuous set of capacity values related to degrees of utilization.

REFERENCES

[1] O. Giuffrè, M. Guerrieri and A. Granà, "Evaluating capacity and efficiency of turbo-roundabouts", CD-ROM. In 88th TRB Annual Meeting. Washington D.C. (United States), 2009. Available: http://pubsindex.trb.org/view.aspx?id=881751

[2] R. Mauro, M. Cattani, "Potential accident rate of turbo-roundabouts" IV International Symposium on Highway Geometric Design TRB (Transportation Research Board), Valencia, Spain 2-5 June 2010. Available: http://4ishgd.webs.upv.es/index_archivos/Page1132.htm

[3] T. Tollazzi, "New Geometric Type of at-grade Intersections: Turbo and Flower Roundabouts Slovenian Guidelines and Experiences". Advanced course in highway and traffic engineering (SIIV), Trento (Italy) 2010.

[4] O. Giuffrè O, M. Guerrieri and A. Granà, "Turbo-roundabout general design criteria and functional principles: case studies from the real world". IV International Symposium on Highway Geometric Design TRB (Transportation Research Board), Valencia, Spain 2-5 June 2010. Available: http://4ishgd.webs.upv.es/index_archivos/Page1132.htm

[5] Fortuijn, L.G.H.. "Turbo Roundabouts: Design Principles and Safety Performance", CD-ROM. 88th TRB Annual Meeting. Washington D.C. (United States), 2009. Available: http://pubsindex.trb.org/view.aspx?id=881758

[6] O. Giuffrè O, M. Guerrieri and A. Granà, "Modello di capacità e valutazione delle prestazioni per le rotatorie a turbina", 17° Convegno Nazionale SIIV. Le reti di trasporto urbano. Enna. 10-12 Settembre 2008. (vol. I, pp. 1-16). ISBN/ISSN: 9788889440407. PALERMO: Edizioni Caracol (ITALY). Available: http://www.siiv.it/documenti/63_2848_20080920114339.pdf

[7] W.Brilon, B.Stuwe, O.Drews, "Sicherheit und Leistungsfähigkeit von Kreisverkehrsplätzen", Institute for Traffic Engineering, Ruhr Universität, Bochum, Deutschland, 1993

[8] HCM 2000, Highway Capacity Manual. Transportation Research Board, special Report 209, edition 2000.

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