

STUDY OF DRIVER BEHAVIOUR AT TURBO-ROUNDBABOUTS

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Abstract: *The article presents the results of preliminary research into the behaviour of drivers at turbo-roundabouts. The subject of the research included the frequency of driver behaviour against the traffic rules, and the speed at which vehicles drive through turbo-roundabouts. One of the crucial problems which was analysed was the influence of different kinds of traffic lane division on the behaviour of drivers. The analysis results affirm that the raised lane dividers can visibly improve the propensity of drivers to stay within the designated traffic corridor. However, it does not eliminate the phenomenon of improper lane changing on circulatory roadway. The physical separation of traffic lanes has not been determined to introduce any additional hazard. The speed of vehicles encroaching upon the neighbouring traffic corridor is visibly higher than this of vehicles following traffic rules. Using crash prediction models developed for single- and multi-lane roundabouts, the authors of the research estimated that lane dividers may reduce the number of crashes from about 10% to 17%.*

Key words: *traffic engineering, road safety, turbo-roundabouts, separation of traffic lanes*

1. Introduction

Road intersections are one of the most demanding elements of road infrastructure to design. They are critical parts of the network, often determining the road safety and traffic performance. Ensuring safety is one of the most important (superior) aims of geometric design, requiring taking into account multiple specific criteria (Tracz et. al, 2001a). One of the safest types of intersections are compact single-lane roundabouts (Tracz et. al, 2001b). Despite several unquestionable advantages of this type of intersections, their application is not always justified or feasible. An example of such a situation would be an intersection of multi-lane roads. Here, one of the traffic lanes would need to be closed or transformed into a bypass (physically segregated right turn lane). The limitation of compact roundabouts resulting from the number of entry lanes as well as circulatory roadway (one lane) translates into the capacity of such an intersection (in favourable conditions estimated to be around 2,500 veh/h). Multi-lane roundabouts provide a higher capacity, however the number of accidents as well as Property Damage Only accidents (PDO) is visibly larger than in the case of single-lane ones. It is the result of the geometric layout, which leads to higher speeds and especially lane change manoeuvres

within the circulatory roadway of the roundabout corresponding to the higher number of collision points. In the light of the above, the compromise solution between road safety and higher capacity is the turbo-roundabout. The turbo-roundabout was first developed by the Dutch who lead the way in their development and operational analysis. Having a large number of turbo-roundabouts allowed them to accumulate experiences, which found their reflection in the first design guidelines for this type of intersections, and in their subsequent updates (CROW, 2008). The Dutch solutions have then been adopted in many countries, including Poland.

Turbo-roundabouts are beginning to be used more and more often in Poland, even though there are no uniform (mandatory) regulations for their geometric design, traffic organization, or capacity analyses. At the same time the current knowledge and degree of research advancement do not yet allow for an unequivocal determination of recommended and incorrect solutions. Lack of design guidelines means a greater freedom for designers, as a result of which different turbo-roundabout solutions are arrived at. These often differ significantly from one another, while displaying a number of characteristic features typical of the Dutch solutions. One of the features which differentiates such intersections is the method

of separating the traffic lanes in the roadway and/or entries into the roundabout. The aim of the present article is an attempt to recognise influence of selected elements from the field of geometry and traffic organization on the behaviour of drivers in turbo-roundabouts, while taking into account the method of traffic lanes division. The identification of the influence of selected geometric features of a roundabout on the drivers' behaviour is indispensable in order to formulate safe and recommended solutions for design.

2. A characteristic of turbo-roundabouts

2.1. Roundabouts design

Turbo-roundabouts are a specific type of multi-lane roundabouts which allow passing through the intersection in given directions in one or more lanes without the necessity to change lanes. They are characterised by a smaller number of collision points due to the elimination of weaving manoeuvres on the roundabout's roadway. This effect is achieved thanks to the spiral layout of traffic lanes. No weaving means that the selection of the traffic lane

must be made before entering the roundabout. The Dutch guidelines define very precisely the design and organisation requirements for a turbo-roundabout (Figure 1). A very rich and detailed characteristic of turbo-roundabouts can be found both in foreign (CROW 2008, Fortuijn 2009, Verweij et al. 2009, FGSV 2014), and domestic literature (Grabowski 2012, Sołowczuk et al. 2013). In the five-stage designing process the geometry of a roundabout including all its elements is chosen, beginning from determining the diameter of a roundabout and the width of its traffic lanes (Verweij et al. 2009). The spiral shape of the roundabout is usually obtained through the geometric shaping of lanes based on an ellipsis or an Archimedean spiral (Grabowski 2012). Designing a roundabout based on an ellipsis allows controlling to a greater extent the deflection of entering traffic, which is useful in reducing the speed of the vehicles passing through a roundabout. Physical separation of traffic lanes supports the improved clarity of a roundabout as well as keeping vehicles in their lane.

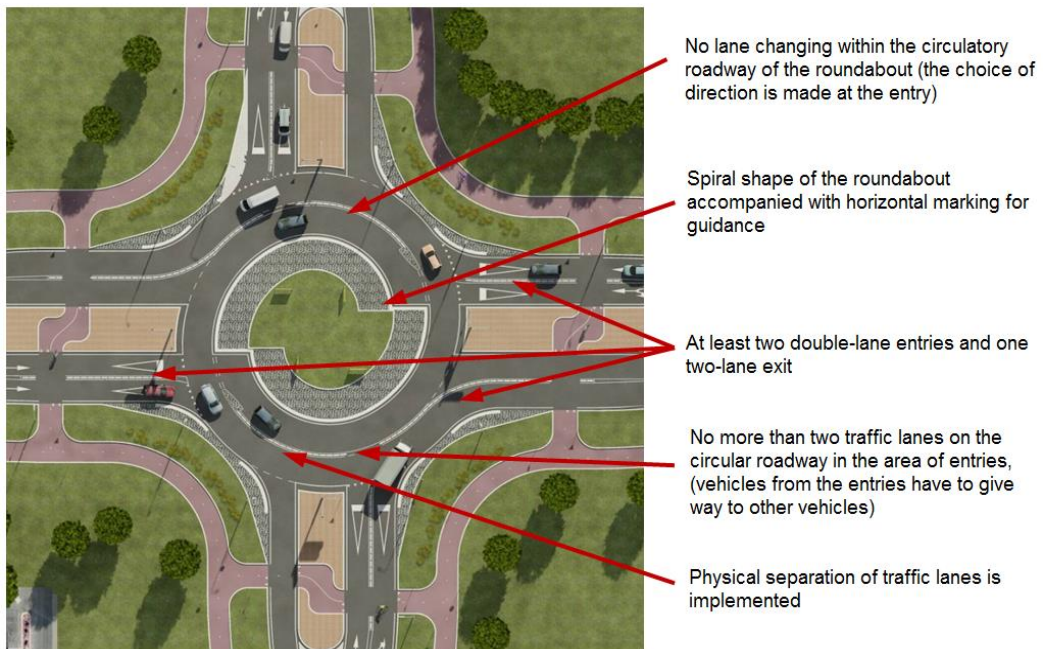


Fig. 1. Characteristic features of a turbo-roundabout

Source: Verweij et al. (2009).

2.2. Methods of separating traffic lanes in turbo-roundabouts

Physical separation of traffic lanes, which is a common feature of turbo-roundabouts should ensure a higher level of road safety in comparison to multi-lane roundabouts, because it precludes waving manoeuvre. The Dutch guidelines (CROW 2008) outline the recommended solutions in details (Figure 2). A concrete curb, raised over the surface of the roadway by 7 cm, is placed at the axis separating traffic lanes (in order to drain rainwater it has gaps every ca. 1 meter). Both sides of the divider are made more visible by marking the roadway with a solid white line. The guidelines require the dividers to be equipped with reflectors on the slopes, which improve their visibility during night time.

In accordance with German technical standards, vertical separation of the traffic lanes is not required (FGSV 2014). Although discipline of drivers is not perfect and encroaching on neighbouring lane is observed, the research has shown that well applied horizontal marking and signing may be sufficient to reduce illegal lane changing (Brilon 2014).

In Poland the physical separation of traffic lanes is often substituted with horizontal marking only (“no passing” solid line). This is due to technical requirements (obstructing drainage and snow ploughing), low social acceptance for this solution and a higher hazard for motorcycle riders (Brilon 2014, Macioszek 2013b). If dividers are implemented, they have different shapes and dimensions. These can be various kinds of road curbs, side barriers, paving, and also pre-fabricated elements. The presence of a divider is not always emphasised with horizontal marking. Examples of solutions are presented in Photo 1, while more can be found in (Macioszek 2013c).

2.3. Road safety

Foreign experiences prove that turbo-roundabouts are a safe solution. However, it is difficult to estimate the potential for reducing accidents by implementing turbo-roundabouts in comparison to other types of intersections. Because of a limited number of analysed intersections and the methodology of analyses, most reports indicating the positive effect of using turbo-roundabouts do not constitute a basis for a credible quantitative assessment. The results of Dutch estimates based on “before and after” analyses show that the potential for reducing accidents is similar to single-lane roundabouts (ca. 70%) (Fortuijn 2009). In Germany, turbo-roundabouts are considered a safe type of intersections, similar to compact one-lane roundabouts. Brillon and Geppert (2011) suggest approximate accident rate equal to 0.9.

Applying their developed potential accident rate model, Mauro and Cattani (2010) determined that the level of road safety hazard defined as the number of injury accidents is around 25-30% lower, while for all collisions it is 40-50% lower than for multi-lane roundabouts. The authors underline the fact that the results were obtained by applying the theoretical model for multi-lane roundabouts to turbo-roundabouts without calibrating, and thus the calculations should be threaten as preliminary indication.

An attempt to estimate road safety was made in Poland based on the data concerning accidents obtained from the database of accidents and collisions in Poland (Macioszek 2013a, Macioszek 2013b, Macioszek 2015). One of the aims of the analyses conducted was to compare the operation of roundabouts with physically separated traffic lanes with those with no raised dividers

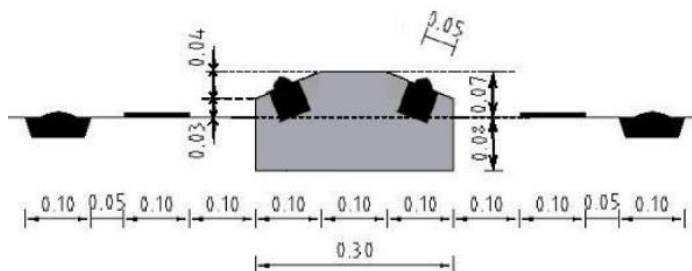


Fig. 2. An example solution of lane dividers in accordance with the Dutch guidelines
Source: CROW (2008), Verweij et al. (2009).

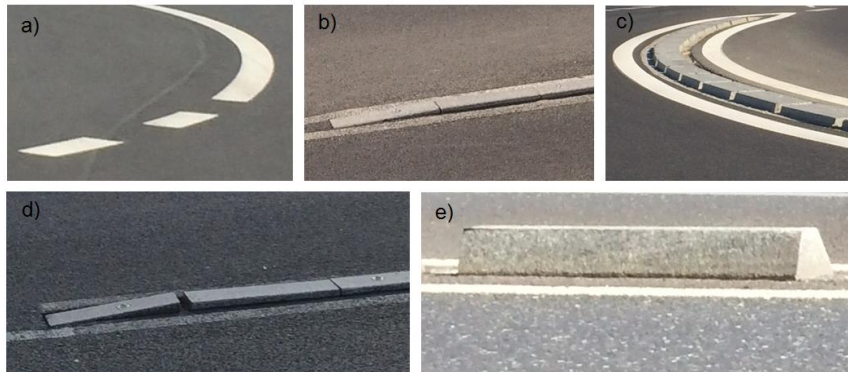


Photo 1. Examples of methods of separating traffic lanes in Polish turbo-roundabouts: a) horizontal marking (Chrzanów), b) low divider (Bielsko-Biała), c) high and massive divider (Świlcza near Rzeszów), d) wide divider with reflexive elements (Chorzów), e) high and impassable divider (Stalowa Wola)

One of the conclusions was that the level of road safety in turbo-roundabouts with no physical separation between traffic lanes was similar to multi-lane roundabouts, while using raised dividers improved safety. At roundabouts with no raised lane dividers 56% of accidents are angle crashes, while with physical separation reduces the share to 24%. Illegal lane changing caused 18% of all crashes for both types of turbo-roundabouts, while failure to give a right of way 30%-40%. This assessment was conducted based on a small number of roundabouts, namely 17.

Since accident data is often limited and inaccurate and there is a difficulty in obtaining the necessary data to carry out a comparison of the relative hazard for road safety on different intersections (such as for e.g. traffic volume), it becomes necessary to develop an indirect safety measures. One of the criteria of such an assessment would be share of improper driver behaviour. Another one could be the speed of vehicles. Speed or speed difference are one of the explanatory variables in modelling accident rates (Turner et al. 2009). Thus relative speed change may be used to predict effects of changes in roundabout geometry on road safety hazard.

3. Study of traffic flow at turbo-roundabouts

3.1. Driver behaviour at the turbo-roundabouts

Due to the preliminary character of the research into the behaviour of drivers at turbo-roundabouts, test sites selected for the research had a noticeable geometrical diversity and a similar organisation of traffic. Characteristic features of the investigated

roundabouts are shown in Table 1. Measurements were carried out in the area of two-lane entries into the roundabout, circular roadway and the exit situated straight ahead. In the majority of roundabouts exiting to the left can take place from the inner lane, exiting to the right only from the outer lane, while through movement may use both lanes. All the roundabouts were originally designed as turbo-roundabouts, and thus they met most of the Dutch requirements (except the roundabout in Tarnów). However, the method of delineating traffic lanes follows an older design method which advises a smooth transition into circular traffic around the island on the entry lanes (CROW 2008). Conventional traffic signs and horizontal marking defined in the Highway Code fail to correspond to the new types of roundabouts. In some instances traffic engineers try to adapt foreign signs to support standard signs and marking. The problems associated with the adaptation of Polish signs and marking to the turbo-roundabouts were described in (Macioszek 2013d).

Traffic measurements in the roundabouts were conducted using a monitoring system allowing for obtaining and processing footage from several cameras. The test site included the approach section to a roundabout (ca. 60 m), the entry, the circulatory roadway around the island and the exit. The obtained video footage made it possible to recreate the trajectory of vehicles of selected streams and to estimate the instantaneous speed for selected cross-sections of the roundabout.

Table 1. Characteristic features of roundabouts under analysis

Roundabout	Świlcza 1 (Rzeszów)	Świlcza 2 (Rzeszów)	Stalowa Wola	Bielsko-Biała	Chorzów	Chrzanów	Tarnów
1 traffic movement; lane layout							
2 separation of lanes in the roadway of the roundabout	raised curb with solid lines on both sides	wide raised curb with solid lines on both sides	high raised curb with solid lines on both sides	low raised curb	low raised curb with solid lines on both sides	horizontal marking only	horizontal marking only
3 separation of lanes at the roundabout entries	raised curb	raised curb	raised curb / marking	horizontal marking	horizontal marking	horizontal marking	horizontal marking
4 delineation of lanes in the roadway of the roundabout	ellipse	ellipse	Archimedean spiral	Archimedean spiral	ellipse	ellipse	ellipse
5 width of lane in the roundabout [m]	5.0	5.0	5.5	5.0	5.0	5.0	5.0
6 D_z : outer diameter [m]	60	60	72	43.5	52	48	64/52
7 D_w : inner diameter [m]	32	32	44	24	32	24	32
8 deflection of the inner trajectory [m]	8.7	17.3	17.3	18.8	5.0	9.6	9.0
9 deflection of the outer trajectory [m]	10.2	19.0	19.0	21.5	6.5	10.9	10.5
10 informational signs & arrows ¹	standard + special sign	conventional sign at the approach	conventional sign at the approach	conventional sign at the entry	special sign	conventional sign at the approach	conventional sign at the approach
11 horizontal marking ¹	arrows (conventional marking)	arrows (conventional marking)	arrows (conventional marking)	arrows (conventional marking)	arrows (conventional marking)	arrows (conventional marking)	arrows (conventional marking)

1 – standard signs and horizontal marking

3.2. Propensity of drivers to follow designated traffic corridors

Specific character of turbo-roundabouts operation may lead to worsening driver decision making process and an increase of driver error. This applies in particular to choosing the correct lane (in relation to the intended direction) on the approach, and to continuing to stay in the designated traffic corridor.

The measurements made in the turbo-roundabouts listed in Table 1 provided a basis for a preliminary assessment of the frequency at which instances of incorrect behaviour occur. Several examples of such behaviour (illustrated in Figure 3) were singled out:

- driving over the edge of the traffic lane (separately for the outer and inner lanes; when it comes to the inner lane of a roundabout this

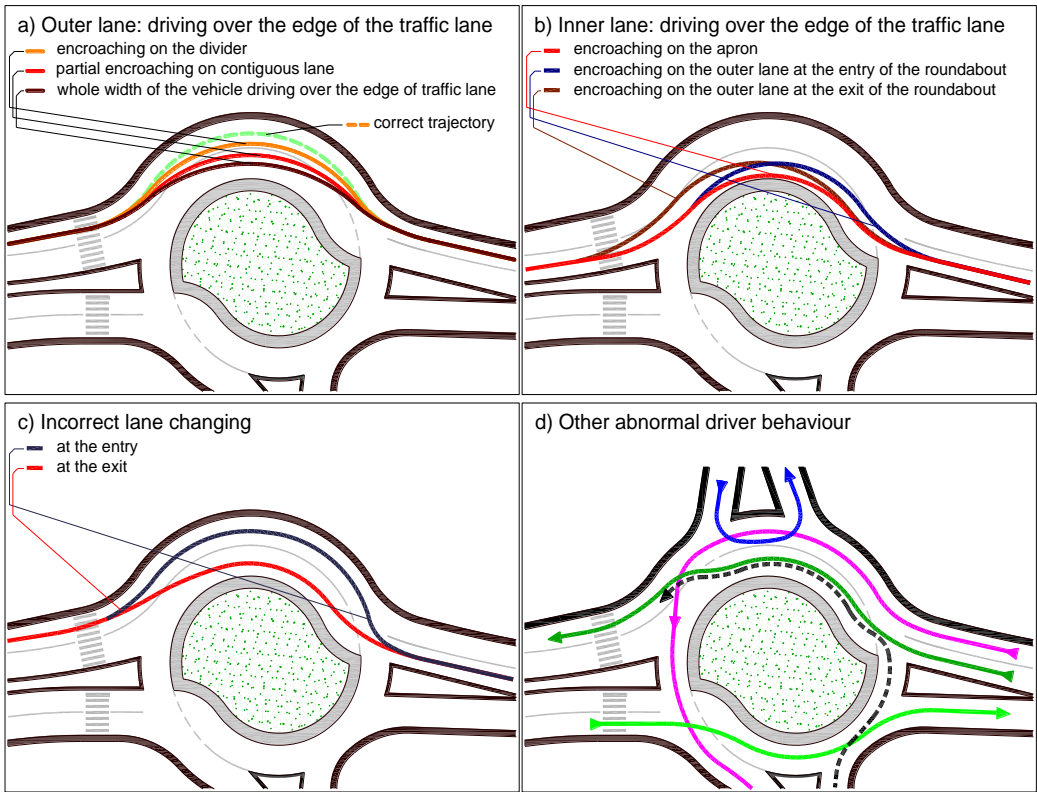


Fig. 3. Incorrect driver behaviours in a turbo-roundabout.

- manifests itself through moving over to the neighbouring traffic lane at the entry or exit, or through unnecessary encroachment on the circulatory road by passenger cars),
- needlessly changing traffic lanes which is not a result of wrong lane selection at entry (changing lanes is not caused by the inability to continue driving in the chosen direction in a given lane),
- passing through a roundabout in other ways which are against the traffic rules (including lane changing in order to continue driving in a direction which is not allowed from a given traffic lane, or even driving in the wrong way).

The conducted measurements confirmed the effectiveness of raised dividers in regulating the traffic at the roundabout. Their presence practically eradicates some illegal behaviour (driving over the edge of a traffic lane – Figures 3a and 3b), but it does

not eliminate the lane changing which can be done in sections with no dividers, intended so as to ensure passability. Figure 4 is a graphic representation of the percentage of drivers using the outer lane while going straight for two roundabouts which have no physical separation between traffic lanes. Fewer than 20% of light vehicles drive over to the neighbouring traffic lane, while a few percent of drivers ignore the horizontal marking entirely and straightens curve. The reverse of this situation (moving from the inner lane onto the outer one), happens much more infrequently and is observed mostly in the area of entries and exits. The roundabout in Chrzanów was characterised by an increased rate of encroaching the neighbouring traffic corridor, which probably has to do with the smaller diameter of the roundabout and with the larger deflection angle formed by the entry and exit axes (Figure 4b).

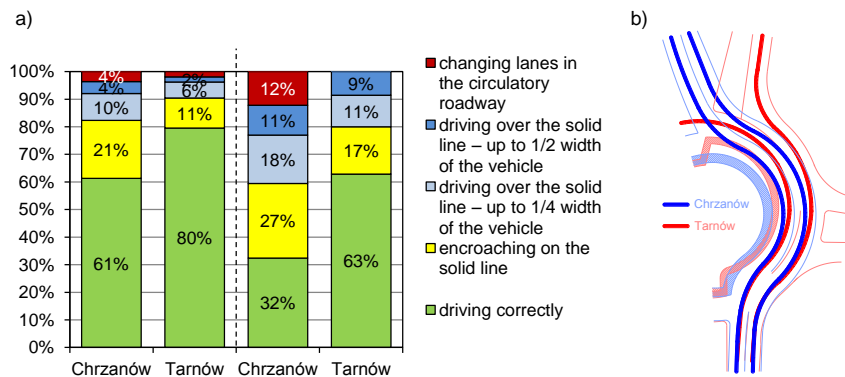


Fig 4. Propensity of drivers in the outer lane to follow the designated traffic corridor at roundabouts with no physical separation of traffic lanes a) empirical data, b) comparison of the geometry and trajectories of passing through both roundabouts

A comparison of frequency at which other incorrect behaviour occurred at all analysed roundabouts is provided in Table 2. These were, among others, instances of: illegal lane changing and encroaching on the neighbouring traffic lane, as well as driving over the truck apron (which is not forbidden but in the case of light vehicles it is not motivated by the demands of passability). In the roundabouts with raised lane dividers encroaching on neighbouring traffic lanes happens mostly in the entry and exit areas. Such situations were most frequent at the roundabout in Bielsko-Biała. This is likely due to the small dimensions of the roundabout (outer diameter $D_z = 43,5$ m, small values of rounding radiuses) and by the fact that the sections along which physical separation of traffic lanes was implemented are very short.

Changing lanes within the circulatory roadway can be the source of the most serious traffic conflicts. When lane dividers are implemented, such incidents

take place above all at the entries and exits. The conducted analyses indicated that the problem occurs mostly at the exits. Only a small number of illegal lane changing was the result of the need to continue driving in a different direction than permitted. The largest percentage of such instances was recorded in Stalowa Wola (45%). It could be explained by low traffic volume, the significant trajectory deflection of the inner lane at the exit, and the ending of the left lane nearby the exit. In the roundabout in Chorzów one could distinguish a group of drivers who changed lanes by moving into the inner lane despite there being no need for such a manoeuvre (this case was shown with a dashed line in Figure 3d), which may mean, among other things, a problem with identifying traffic lanes caused by the geometric layout of the entry and/or with unfamiliarity with driving rules in turbo-roundabouts.

Table 2. Improper behaviour at turbo-roundabouts

Roundabout	outer lane			inner lane		
	lane change at the entry	lane change at the exit	driving over the line	lane change at the entry	lane change at the exit	driving over the apron ¹
1 Bielsko-Biała	0.0%	0.0%	11.5%	0%	0%	1.5%
2 Świlcza 1	0.0%	0.0%	0.0%	0.8%	-	0.0%
3 Świlcza 2	0.0%	0.0%	0.0%	0%	0%	2.3%
4 StalowaWola	0.6%	0.0%	0.0%	1.8%	43.3%	-
5 Chorzów	-	0.3%	0.1%	0.2% ²	1.2% ²	1.0%
6 Chrzanów	2.2%	-	2.0%	2.5%	5.5%	2.5%
7 Tarnów	0.1%	-	-	0.0%	1.28% ²	1.9%

1 – concerns light vehicles
 2 – changing lanes is related to continuing in the desired direction

Instances of illegal behaviour turned out the least frequent in the roundabouts in Świlcza, even though it was there that one could expect the largest number of drivers who are unfamiliar with the road (as the roundabouts are part of a freeway interchange). In these roundabouts traffic lanes are separated with a massive divider, both in the roadway and at the entry, which, together with very clear signs and horizontal marking, brings about the desired effect.

3.3. Vehicle speed at turbo-roundabouts

The low speed at which vehicles pass through roundabouts is one of the reasons for the number of accidents being small, and especially for the limited severity of incidents (according to Macioszek (2013c), registered PDO collisions account for ca. 95% of accidents). The speed of vehicles passing through roundabouts may also be useful in developing models of capacity of roundabouts (Macioszek 2013a).

The measurements of instantaneous speed were made by measuring the time of passing through the given sections. Five sections were singled out (Figure 5):

1. approach section,
2. entry area (ca. 20 m of the entry to the stop line),
3. conflicting area,
4. circulatory roadway,
5. exit area.

Analyses were conducted separately for the outer and inner lanes, dividing the vehicles into light ones (passenger and delivery cars) and heavy ones (buses and trucks). Due to a small presence of heavy vehicle traffic, a statistically reliable sample for this category was obtained only for a few streams.

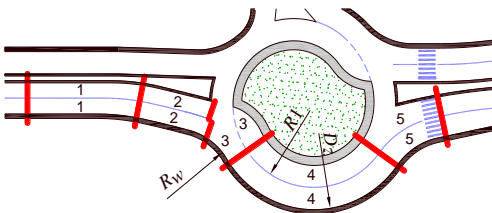


Fig. 5. Measurement distances for instantaneous speed

Figure 6 presents the profiles of speed for passenger cars driving straight ahead in the outer lane. The

speed of light vehicles at the entry of the roundabout (distance 3) varies between 20 km/h and 28 km/h in the outer lane and between 23 km/h and 37 km/h in the inner lane. Higher speed for the inner lane may be the result of a better visibility of the circulating flow (vehicles on inner lane impeded visibility) as well as greater rounding radius. The largest differences between speed at the conflicting area (3) were recorded in roundabouts with no physical separation between traffic lanes. In the circulatory roadway (section 4) slightly higher speed was registered in the outer lane, which can be explained by the greater radius of this lane. The speed at the conflicting area does not have impact on the speed in the roadway of the roundabout for both traffic lanes, with the correlation rate being -0.33 (it is also difficult to find a physical interpretation for this negative figure).

It would seem that the method of separating traffic lanes may have an important impact on the speed at the conflicting area of a roundabout. Much higher speed in the conflicting area (about ca. 10 km/h) was observed in the inner lane in comparison with the neighbouring lane: when the lanes were separated only with horizontal marking, while in these roundabouts with dividers this difference amounted to 3 km/h on average. Juxtaposing the speed at circulatory roadway in roundabouts with the physical separation of traffic lanes also reveals significant differences: in the first case the mean speed was 27 km/h, while for roundabouts without dividers (curbs) it was 35 km/h.

The search for the influence of geometric features on the speed of vehicles passing through a roundabout was conducted separately for the outer and the inner lanes. It should be stressed that these analyses have preliminary character and are aimed predominantly at setting new directions in the construction of speed models for traffic in turbo-roundabouts, rather than at formulating conclusions of statistic relevance.

None of the geometric parameters characterising a turbo-roundabout did not turn out to be a relevant factor determining the speed of vehicles at the entry area and in the roadway of the roundabout (Figures 7c and 7d). The best correlation was obtained for the relation between the external diameter of the roundabout and the speed of vehicles passing through the circulatory roadway (coefficient of determination R^2 was 0.29 and 0.39, for the outer and inner lane respectively).

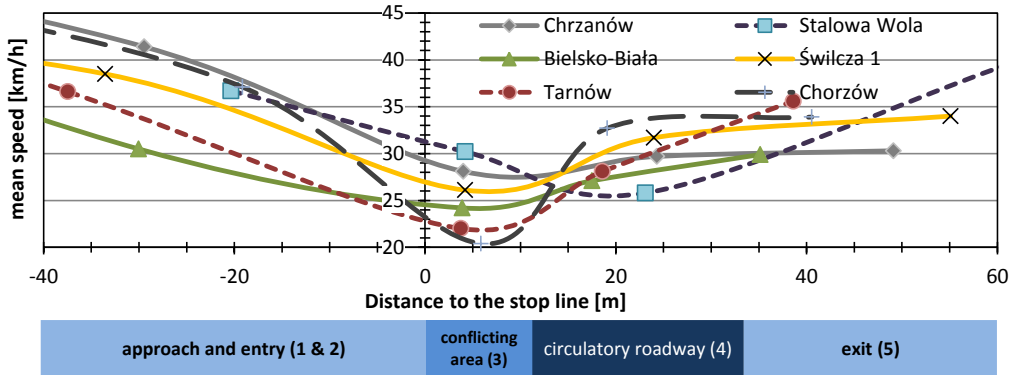


Fig. 6. Free flow speed profiles for passenger cars passing straight ahead through turbo-roundabouts (outer lane)

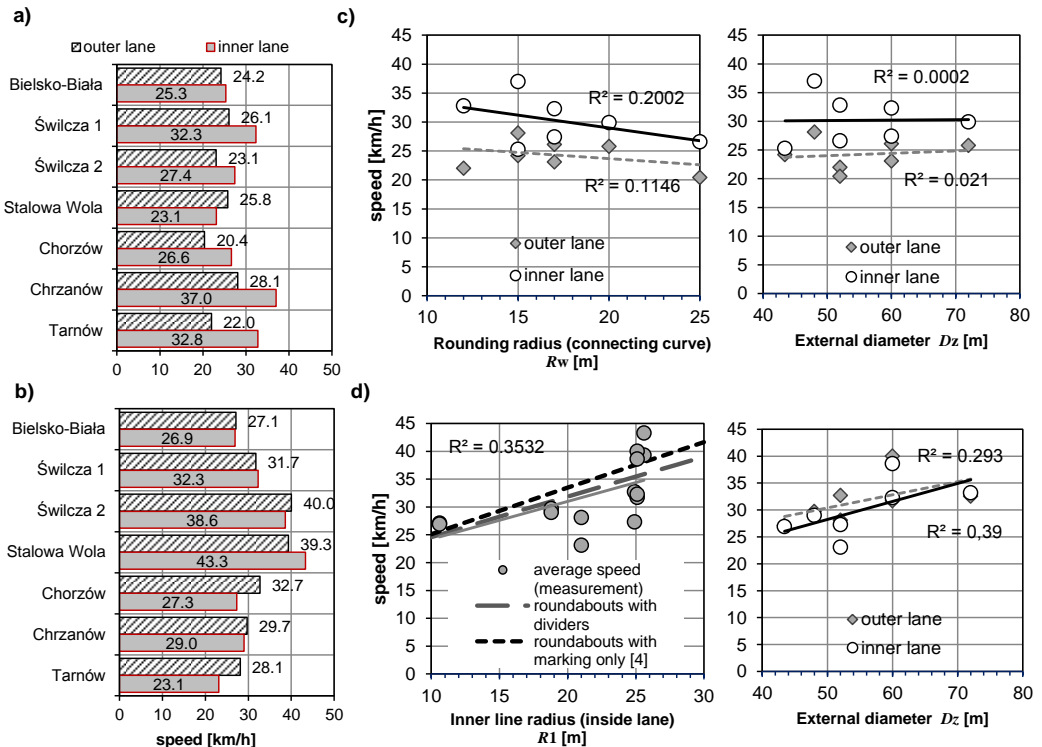


Fig. 7. Comparison of mean speed a) in the outer and inner lane in the entry area, b) in the circulatory roadway, c) impact of the R_w radius at the entry and the external diameter of the roundabout (D_z) on the mean speed of passenger cars at the entry area, d) impact of R_1 and D_z on the mean speed of vehicles in the circulatory roadway

Obtained results (Figure 7d) were convergent with the speed model presented by Macioszek (2013a), in which the only independent variable is the radius $R1$ (the first radius of the roundabout's circular path). The rounding radius at the entry to the roundabout does not have a significant impact on the speed of vehicles. Similarly weak correlations were obtained for the deflection of trajectory and the rate of expansion. Since designing turbo-roundabouts is more complicated than that of traditional one- and multi-lane roundabouts, the influence of geometry on speed may prove much more difficult to describe and require taking into account several factors in the model. The limited number of roundabouts analysed does not allow to describe speed using a multiple regression model.

For the roundabouts with no physical separation of traffic lanes, a comparison (Figure 8) was conducted between the speed of vehicles staying within the designated traffic corridor and those driving over from the outer to the inner lane (cutting corners). Higher speed is observed already at the approach section. The differences in speed are statistically significant ($\alpha = 0.05$). The vehicles driving over the solid line or driving slightly outside of their designated traffic corridor were moving at speed similar to this of the vehicles which were driving in accordance with the horizontal marking.

Raised lane dividers may have influence on crashes at conflicting area. According to speed model presented in (Macioszek 2013a) and the results shown above, lane dividers slightly reduce speed at circulatory roadway. Vehicle speed is one of the most important non-flow variables in crash prediction models. The model for single and multilane urban roundabouts developed by Turner et al. (2009) has

been used to present impact of lane dividers on road safety:

$$A_{CCE} = 6.12 \cdot 10^{-8} \cdot Q_e^{0.47} \cdot Q_C^{0.26} \cdot S_C^{2.13}$$

where:

A_{CCE} = annual number of entering versus circulating crashes involving motor vehicles only

Q_e = entering flow on the approach

Q_C = circulating flow

S_C = free mean speed of circulating vehicles as they pass the approach being modelled.

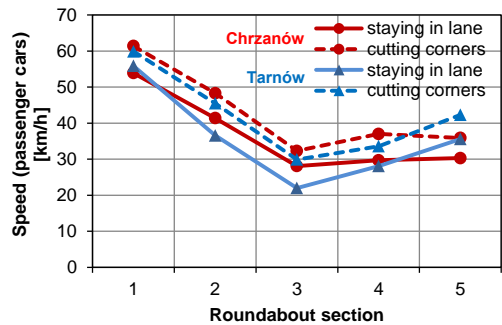


Fig. 8. Comparison of the mean speed of vehicles staying in the designated traffic corridor and those cutting corners

Since the raised lane dividers reduce the mean flow speed ca. 1.5 km/h (Macioszek 2013a) as well as the number of vehicles travelling at higher speeds which cut corners on circulatory roadway (figure 8), the number of crashes at conflicting area decreases by 10% to 17%. Figure 9 illustrates the influence of implementing lane dividers in roundabouts on crash reduction.

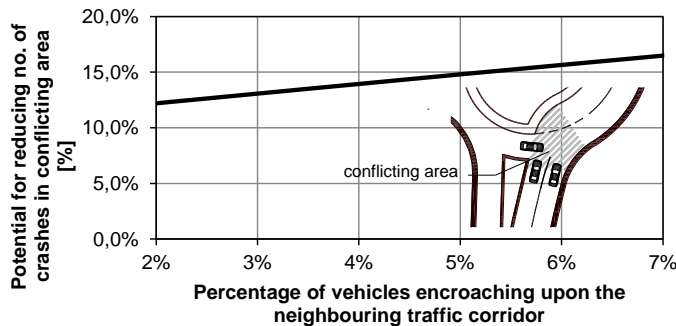


Fig. 9. Influence of raised lane dividers on road safety improvement

It should be taken into consideration that the presented results are only indicative. The selected crash prediction model has been developed for standard roundabouts. The relationship between geometry and vehicle speed in turbo-roundabouts may differ significantly. However, a positive effect of raised lane dividers is visible and highly probable

4. Conclusions

The turbo-roundabouts which are being built in Poland create an opportunity to improve the traffic performance and road safety in critical points of the road network. The considerable diversity of solutions applied in these roundabouts is not only the result of traffic circumstances, but it is also determined by the lack of nationwide design guidelines as well as of any method of evaluating their efficiency. There has been no wide-scope information campaign aimed at promoting these new solutions for intersections which, as far as traffic rules go, are a cross between a channelised intersection and a circular intersection. It may trigger various behaviour in drivers passing through them, including anomalous behaviour.

The conducted study shows that drivers pass through roundabouts in a self-assured way, and the percentage of drivers violating in a clear way the traffic rules and the logic of turbo-roundabouts is usually below a few percent. Illegal lane changing occurs most frequently in the exit area. The physical separation of traffic lanes has not been ascertained to create an additional hazard, while it expedites the propensity to stay within the designated traffic corridor and can contribute to slowing down at the entry to a roundabout.

The analysis of speed of the vehicles passing through a roundabout demonstrated a speed differentiation in the inner and outer lanes, where at the entry onto the circulatory roadway higher speed is noticed in the inner lane, while at the roadway of a roundabout the vehicles moved with a minimally higher speed in the outer lane. The difference in speed in neighbouring lanes by the entry on to a roundabout is much smaller if lane dividers are implemented. The possibility of driving over the edge of the lane when physical dividers are absent leads to a statistically pertinent increase in speed of vehicles straightening their path when passing through a roundabout.

The presented analyses should be treated as preliminary. They point to the necessity of conducting further research into the functioning of turbo-roundabouts from the point of view of safety, with particular attention paid to speed of vehicles.

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