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Conversion of a semi-two lanes roundabout into a turbo-roundabout: a performance comparison

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Abstract

In the last years, as regards the functional design of at-grade intersections, near to classic layouts (signal-controlled junctions, roundabouts, etc.) a new solution has born: the “turbo-roundabout”. It is a canalized multilane oval intersection with a non-traversable or partially traversable center island and with a spiral circulatory carriageway. This kind of roundabout is also characterized by a predictable lane use: some direction flows are physically separated by curbs. Several roundabouts with spiraling circular carriageways were built in northern Europe (in particular in Netherlands) and they have further allowed to extend the notable advantages of this functional solution against multilane roundabouts, such as: 1) no lane changing on the circulatory carriageway; 2) no need to yield to traffic flow on more than two lanes; 3) low driving speed along the through movement because of raised lane dividers and, consequently, a high reduction of accident risk. In this paper a careful literature review on turbo-roundabouts is proposed. Furthermore, the Authors examine the potentialities offered by the transformation of an existing semi-two lanes roundabout into a "virtual" configuration of a turbo-roundabout. In particular, they also evaluate and compare the performance parameters in the two configurations by using a microsimulation software. The case study roundabout is placed in the city of Cosenza (Southern Italy) and it is characterized by great problems of congestion during peak hours. Experimental measures of traffic flows (O/D matrixes), critical gaps, queue lengths and approaching and circulating speeds represent input data for calibration procedures. Afterwards, derived calibration parameters are used as input variables for the new configuration of the intersection as a turbo roundabout. The Authors highlight that the conversion of the existing roundabout into a virtual turbo roundabout determine an increase of capacity together with a minimization of the queue lengths.

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Keywords: Turbo-roundabout; microsimulation tool; roundabout capacity; queue length; calibration procedure.

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1. Introduction

In the last decades, roundabouts have been recognized as a safer and more efficient solution than traditional priority junctions[1-6]. Since some years, a further step towards this research field has been taken by the evolution of multilane roundabouts into the so-called "turbo-roundabouts", in order to increase both safety and traffic performance of this kind of intersections[7-9]. Multilane roundabouts are useful when traffic demand is so high that single lane intersections are not adequate in terms of capacity. However, they offer a significant movement freedom to drivers that often adopt incorrect trajectories, thus leading to weaving conflicts and traffic injuries in the circulatory carriageways. Moreover, drivers tend to assume higher speed when cutting trajectories curvature. Previous studies on multilane roundabouts in Portugal[10,11] showed that drivers in free flow conditions behaved as follows: i) more than 40% that entered the roundabout using the right lane (outside) followed straight line trajectories, thus invading the left lane; ii) on the contrary, more than 20% of drivers using the inside lane (on the left) tended to exit from the circulatory carriageways using the right lane, without looking at road marks. This behavior is strictly related to roundabout deflection levels[2]. Therefore, there is the need of a correct design strategy which takes into account wider carriageways and cross sections at the entry and exit. Turbo roundabouts represent an evolution of roundabout design, which was introduced in Netherlands[8] in 1996, in order to reduce the previously highlighted problems, increasing the capacity of intersection without affecting efficiency. As regards geometry, turbo roundabouts are characterized by a spiraling circular carriageways with physically separated lanes (with no mountable curbs also on the ring) into which traffic flows are forced to merge. The physical separation of traffic lanes is only interrupted at the entry into the inner circulatory carriageway. This solution implies that drivers have to choose their direction before entering the intersection, thus reducing the number of conflicts points (from 24 for a traditional double lane roundabout with four legs to 14) and, consequently, the risk of side-by-side accidents[12-14]. The raised line dividers constrain drivers to follow paths with lower radius and to reduce their speed; moreover, speed profiles are highly homogeneous because all drivers must follow the same paths. Despite the safety benefits derived from this solution are well known, more research is needed to analyze capacity improvement and delay reduction. In the light of the above, in this paper a virtual configuration of a turbo-roundabout is proposed as an alternative configuration of an existing semi-two lanes roundabout located in the city of Cosenza (in Southern Italy) in order to evaluate the potential increase of operational performance[15,16]. Experimental measures of traffic flows (O/D matrixes), critical gaps, queue lengths and speed distributions were used as input data for calibration procedures by a microsimulation software (PTV Vissim)[17,18]. Microsimulation was implemented by the specification of: i) distribution and assignment of traffic flow in time and space; ii) implementation of circulation rules: approach speed, reduced speed zones, circulatory speed zones and priority rules; iii) setting up of scenarios to be analyzed (choice of geometric and traffic variables). The suitability of the compared intersections was estimated in terms of queue lengths at each entry.

2. Literature Review

Several previous studies confirmed the advantages derived from the implementation of turbo-roundabouts instead of the traditional double lane ones. In particular, in the study conducted by Mauro and Cattani[19], the authors evaluated the safety improvement of turbo-roundabouts by applying a potential accident rate model which was based on the concept of potential conflict. Many crash typologies that can occur at an intersection were considered, such as collision for failure to yield, loss of vehicle control, rear-end at entry and circulating-exiting collisions. Results showed that turbo-roundabouts reduce total crashes of about 40-50%, and injury crashes of 20-30%. A more recent research[20] confirmed the previous results, also highlighting the effectiveness of turbo-roundabouts in urban context, where the pedestrian and two-wheeler traffic level is significant. According to the results of before-after studies carried out by Fortuijn[8] in Holland, the effect of a turbo-roundabout on traffic safety is comparable to that of single lane roundabouts with a reduction of about 70% of accidents frequency. Also Vasconcelos et al.[14] confirmed that turbo-roundabouts represent an adequate solution as regards safety because of a consistent reduction of conflict points, although the same authors showed that these last are more severe due to the increased angle between entry and circulating trajectories. In terms of capacity, they concluded that turbo-roundabouts offer better performance than two-lane roundabouts only when the proportion of right-turns at the minor entries right turns is abnormally high