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Capacity and operational improvements of metering roundabouts in Spain

Mariló Martín-Gasulla[1*], Alfredo García[2], Ana Tsui Moreno[3] and Carlos Llorca[2]

[1]Fundación Agustín de Betancourt, Escuela de Caminos, Canales y Puertos; Universidad Politécnica de Madrid, Spain

[2]Highway Engineering Research Group, Universitat Politècnica de València (Spain)

[3]Department of Civil, Geo and Environmental Engineering, Technical University of Munich, Germany

marilomartingasulla@gmail.com, agarciag@tra.upv.es, ana.moreno@tum.de, carlloga@cam.upv.es

Abstract

Metering systems can improve traffic operation and capacity on unbalanced flow roundabouts. This research verified the increase on the proportion of long gaps on the conflicting flow after metering, which lead to longer entering platoons and shorter follow-up headways. In contrast with previous studies, potential benefit was quantified according to the Highway Capacity Manual (HCM) analysis procedure. The reduction in delay is significant at every entrance flow level; and capacity could be doubled for high conflicting flow rates.

Keywords: Roundabout, Unbalanced flow patterns, Capacity, Traffic performance, Metering, Follow-up headway, Platoon

1 Introduction

A widely used method to prevent and/or relieve highway congestion is to control the demand by means of on-ramp metering (Munoz and Horowitz, 2003). Same basis can be translated to roundabouts with unbalanced flow patterns, as it has been applied in Australia (Akçelik, 2004; Andjic, 2013) and recently in the U.S. (Hummer et al., 2014). So far, many of its advantages, in terms of measures of effectiveness, have been widely analyzed.

Metering signals on roundabouts are based on creating gaps in the circulating stream in order to alleviate excessive delays on the main approach of the roundabout during peak hours (Akçelik, 2011, 2008, 2005, 2004; Natalizio, 2005). They should not be planned for metering unless unexpected demand dictates this need after construction (Federal Highway Administration, 2000).

[*] Previous affiliation: Highway Engineering Research Group, Universitat Politècnica de València (marilomartingasulla@gmail.com; anmoch@cam.upv.es)

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Metering basic scheme is composed by a metered approach and a controlling approach (Akçelik, 2004). The metered approach is the one whose demand contributes the most to the conflicting flow in front of the main downstream approach, which is the controlling approach. The controlling approach suffers from long queues and excessive delays due to the right of rule. Metering signal is implemented on the metered approach, while queue detectors are placed on the controlling approach. Red signal displays on the metered approach in order to create greater gaps in front of the controlling approach; and the roundabout overall traffic operation is improved. Maximum red time is introduced to avoid excessive queue on the metered approach. The roundabout reverts to normal operation during a minimum blank/amber time or as long as the controlling approach does not present queuing conditions.

Akçelik (2005) presented the basic principles of operation of metered roundabouts. He studied one-lane, two-lane and three-lane roundabouts in Australia and the USA (Akçelik, 2011, 2008, 2005, 2004). Based on a self-developed aaSIDRA gap-acceptance model using field data from a large number of roundabouts in Australia; queue length, signal timing and other operational parameters on metered roundabouts were determined. In order to improve cycle timing for metering at Australian roundabouts, Akçelik (2011) analyzed entering platoon flow rates. The effective red and effective green times were calculated and proposed to determine the cycle timing. The results indicate that low cycle times produce better intersection performance compared with longer cycle times used in practice.

Natalizio (2005) used a traffic microsimulation in aaSIDRA to analyze traffic flow conditions at urban single-lane roundabouts without the influence of metering signals and tested the theoretical analysis model developed by Akçelik, (2005). Operational benefits on average delay and queue lengths were reported for certain flow conditions on the controlling approach, as well as guidance on optimal metering signal timing. However, they were not compared to the HCM thresholds for roundabouts.

Hummer et al. (2014) developed a simple macroscopic model based on the HCM equations and validated it using VISSIM. This microscopic software allows an accurate implementation of the roundabout geometry. The validation was set to replicate the roundabout capacity relationship of the HCM, and as a result the car-following parameter and speeds in reduced area were modified. Default values of critical gap and follow-up headway were considered. Analytical delays were computed for one cycle length and metering signal location, proving the benefits of metering. Criteria for signalized intersections were used (delay over 80 seconds) to indicate operational benefits. Both single-lane and two-lane roundabouts were analyzed.

More than 30,000 roundabouts with a variety of locations and sizes are implemented in Spain (Romana, 2011) and many of them work over capacity and present unbalanced flow patterns. Given the potential benefits of metering, a previous research on metering roundabouts was carried out (Martin-Gasulla et al., 2016). Geometry and main gap-acceptance parameters were obtained from the field and used to calibrate the VISSIM software. The optimal metering signal scheme was selected from almost 400 combinations of distances and timings, based on the reduction of the average delay of the controlling approach, average queue length and average delay on the roundabout. Using this signal scheme, entering flow and conflicting flow were varied between 0 and 1,600 veh/h; and 0 and 1,200 veh/h, respectively. For each pair of entering and conflicting flow, operational improvements were quantified in terms of average delay. Average delay improved between 10 and 60 % after implementing the metering system. However, capacity improvement was not analyzed in terms of the HCM (considering as threshold LOS F, which is associated with an average delay of 50 s).

The operational improvement of metered roundabouts is based on creating greater gaps on the conflicting flow that could be used as a relief for the congested approach. Even though the positive results, this hypothesis has not been verified yet. Moreover, the potential benefit of metering roundabouts has been focused only on near-capacity conditions; and usually in terms of average delay variation between the metered and unmetered scenarios. The conclusions of the previous studies could not be adequately correlated with the HCM level of service F for roundabouts, as the threshold of 50 s average delay was not considered. Therefore, there is a need to analyze the gap distribution on the