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Original Research Paper

Analyses of maximum-speed path definition at single-lane roundabouts

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HIGHLIGHTS

- Models for roundabout speed provide speeds substantially different from measured.
- Developed methodology enables precise definition of vehicle path and speed.
- This article experimentally determines path elements, which is different from those recommended by the USA guidelines.
- Vehicle path is the basis for development of new operating speed model.

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ABSTRACT

The process of designing roundabouts is an iterative process through which, in several checks, the design elements of a roundabout get optimized. Existing regulations for roundabouts involve swept path analyses, sight distance analyses and speed analyses of vehicles passing through the roundabout. Speed analyses are done mostly based on two models, Dutch and American. Each of these two models, in their own way takes into account design elements of the roundabouts, and the US model also envisions the construction of vehicle paths through the roundabout. Main assumption of both models is that vehicle paths through roundabouts consist of few connected radii. US models for path definition takes into account safety distances from marked lines and geometric elements (curbs) at the entrance and exit and through roundabout. Experimentally determined elements of the vehicle path through the roundabout, do not correspond to those recommendations. Comparison of the measured speed at the roundabouts and speed calculated according to aforementioned models at several roundabouts in Croatia, showed a significant difference. An experimental research was conducted as a first step in developing a new model for operating speed through roundabouts. The research aimed to define the basic path elements of vehicle movement in the roundabout at which the maximum speed is achieved. Results of the study are presented in this paper.

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1. Introduction

During last decades, roundabouts have been successfully implemented as a solution for intersection reconstruction in the cases where there are problems with traffic safety (Elvik, 2003; Jensen, 2013; Retting et al., 2001) or capacity (Kennedy et al., 2005). In their overview of roundabout design and practices, authors came to the conclusion that geometric design criteria have fundamental importance to achieve the best performance of roundabouts in terms of both capacity and safety (Montella et al., 2013). Geometric elements for roundabout design are usually defined through official, mostly national design standards and/or guidelines in which an overview of important geometric elements together with their average values is given. To assure the consistency of chosen geometric elements, roundabout design is then optimized through an iterative process which includes check-up of path-alignment for chosen design vehicle, check-up of sight distance conditions at the entrance and in the roundabout and check-up of operating speed through roundabout. Researches done on roundabouts show that higher operating speeds at the entrance, in the middle of roundabout and at the exit of roundabout can result in traffic accidents and low speeds can negatively affect roundabout capacity or capacity of corridor with more roundabouts in line. Analyses of traffic accidents on roundabouts conducted as a part of extensive studies in USA proved that more than 65% of the most part of the accidents that happen on roundabouts in different parts of the world (Rodegerdts et al., 2010), happened during negotiations at the entrance of the roundabout, loose of control at the entrance and in the roundabout or as rear-end crashes when vehicles brake suddenly at the exit. Analyses of the reasons for those accidents conducted in the same study show that they are different but that in all cases the problem is operating speed of vehicles that participated in the accident.

Comparative study done on the sample of roundabouts in four Middle-European countries (Checkia, Hungary, Poland, Slovakia) was based on the analyses of accidents, traffic and geometry data. According to the finally developed accident prediction model in that study, injury accident frequency is positively associated with effect of traffic volume and apron width, while negatively associated to deflection in terms of both entry and deviation angles (Ambros et al., 2016). A similar study was conducted in South Korea, where the authors have developed a model that predicts an accident at the traffic intersection, solely on the basis of geometric elements intersection (Kim and Choi, 2013).

In their paper about models for relating roundabouts safety to predicted speed authors defined approach average speed (defined as average speed on entry, upstream circulating and exit speed) to be the speed that best predicts safety on roundabouts (Chen et al., 2013).

The conclusion in USA guidelines is that speed represents a fundamental issue for road design and traffic engineering studies, and it is considered as the most important variable in roundabout geometric design (FHWA, 2000). Roundabout design is iterative process in which the selection of geometric parameters highly depends on design speed, estimation of roundabout functionality (safety, capacity) and optimization of the design depends on operational speed. Operational speed on roundabouts can be defined as speed achieved from most of the users while driving through roundabout. When new roundabout is designed, operational speed can be established by using one of the other models for existing roundabouts operational speed (Bassani and Sacchi, 2012). Operational speed is commonly defined as 85% of cruising speed on road section in defined conditions (AASHTO, 2001). In literature, 85% of cruising speed shows the speed of the most conservative driver and that is the reason why it is accepted as operational speed comparing with design speed. The difference between design and operational speed has to be minimum to assure expectations of the most accurate drivers (Bassani et al., 2014). Researches show that speeds measured on road network are often significantly higher than design speeds and also higher than allowed speeds (Wang et al., 2006). Previous research concluded that operational speed at roundabouts highly depends on the vehicle path through the roundabout. Montella et al. (2012) emphasized in their overview on application of entry path radius at roundabouts that the fastest path allowed by the geometry is “the smoothest, flattest path that a vehicle can take through the entry, round the central island and thorough the exit in absence of other traffic”. Al-Ohmari et al. (2014), on the basis of filed investigation on 30 roundabouts, concluded that the average and 85% roundabout circulating speeds are directly proportional to the upstream approach free flow speed, entry width, internal circle diameter, and drive curve, while they are inversely proportional with entry angle.

Silva et al. (2014) in their paper presented a different method of gathering data about vehicles' speed through double-lane roundabout by using a data logger device. Regression analysis showed that roundabout influence zone and entry speed at double-lane roundabouts are strongly related to the approach speed, but some other geometric elements of the roundabouts are statistically significant as well.

In their paper, Easa and Mehmood (2004) presented their model of consistency for roundabouts which is based on the analyses of vehicle path through roundabout (straight, left and right path) in order to assure conflicting and consecutive speed is up to be 20 km/h.

Procedures for estimating design-vehicle path and speed are defined in most of the existing national regulations for roundabouts design. In the following research analyses of following regulations have been done: USA (FHWA, 2000), Australian (Velth and Arndt, 2011), UK (HA, 2007), Netherlands (CROW, 1998; DMT, 2009), Slovenia (MPRS, 2011), Serbia (PS, 2012) and Croatia (HC, 2014).

Models that are used for speed definition in the procedures defined for speed control at roundabouts can be divided in two main groups:

- models based on the calculation of the speed in horizontal curve suggested in FHWA (2000), developed in AASHTO (2001) – FHWA model.
- models based on the correlation of basic design elements suggested in CROW (1998), HC (2014), MPRS (2011) and PS (2012) – CROW model.

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