Roundabout

Subjects: Transportation
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Challenges that emerge in roundabout design are mostly related to space constrictions and provision of appropriate deflection around the central island. This can result in speed profiles on roundabouts that might reduce their potential as a noise abatement measure. Because of this, the impact of a roundabout on noise levels and its applicability as a traffic calming device and a noise abatement measure should be investigated in the early design stage, by modeling noise levels.

Keywords: noise emission model ; fastest path ; relative speed

1. Introduction

The goal of sustainable transportation is to protect the environment and conserve resources while taking into consideration societal needs as well as benefits and costs [1]. Numerous studies have shown that the abovementioned sustainability goals can be achieved in road traffic network planning, design, and management by the introduction of modern roundabouts in the road network. According to [1][2][3][4][5][6][7][8][9][10][11][12][13][14][15], these intersections have proven to be very successful at improving safety (due to the reduced number of conflict points and lower speed compared to the traditional intersections) while enhancing mobility by reducing the total delay compared to other controlled intersections. Moreover, modern roundabouts usually perform better than traditional intersections with traffic lights in terms of environmental sustainability. Previous studies have shown that the application of roundabouts can help reduce the excessive emissions and fuel consumption associated with idling time, acceleration, and deceleration of vehicles that usually occur on traditional intersections with traffic lights, as well as noise pollution in the vicinity of road intersections. Reported average reductions varied from 21 to 42% in emissions of carbon monoxide, 16–59% in emissions of carbon dioxide, 20–48% in emissions of oxides of nitrogen, 18–65% in emissions of hydrocarbons, and from 1 to 4 dB(A) in noise emission [2][9][11][12][13][16][17][18][19][20][21][22][23][24][25][26].

2. Modeling the Influence of Roundabout Deflection on Its Efficiency as a Noise Abatement Measure

Since noise pollution is still considered a major environmental health problem in Europe [27], and since road traffic is the dominant noise source in urban and suburban areas, the noise abatement opportunities should be an integral part of every road planning, design and/or reconstruction process. In urban areas, the average vehicle speed is low (50 km/h or lower), so the road traffic noise level is influenced by vehicle speed, acceleration, and deceleration [18][28][29]. To achieve a required reduction in noise levels, it is necessary to match the physical layout of the road to the intended speed and to provide as smooth a driving pattern as possible [18]. Modern roundabout, as a traffic calming device on which operating speed depends on the geometry (deflection around the circular island) [30][31], and a device that can carry smooth traffic flow by minimizing the start–stop operations of drivers, fulfills the abovementioned requirements for the effective noise abatement measure.

A smooth speed profile through the roundabout is achieved by ensuring the clarity of the situation for approaching drivers, visibility between road users, comprehensibility of traffic operations, and appropriate accommodation of the design vehicles. This means that the impact of a modern roundabout on noise reduction is directly linked to the quality of its design. Roundabout design is an iterative process that consists of the identification of initial design elements, performance checks (the design vehicle swept path analysis, the definition of the fastest path, and visibility tests), and final design details. A good design results in the smooth curvature, channelization, and deflection required to achieve consistent speeds, and appropriate sight distance. As mentioned above, to achieve the required reduction in vehicular emissions, the speed profile through the roundabout must be as smooth as possible [32][33][34]. This can be ensured in the roundabout's designing phase by conducting the abovementioned performance checks, specifically the definition of the fastest path through the roundabout. This performance check aims to determine the negotiation speed for a particular movement into, through, and exiting the roundabout, and the relative speed between consecutive geometric elements as well as between conflicting traffic movements. If the determined relative speed is high, large decelerations and accelerations will occur, which will result in negative impacts on drivers and on the road environment. Therefore, according to [30], the maximum relative speed on traffic calming devices such as roundabouts should be less than 20 km/h.

Environmental benefits of the introduction of modern roundabouts in the road network in terms of their noise reduction capabilities can be determined either by field measurements [2][11][12][13][22][24][26][35][36][37][38][39][40] or by physical modeling, using established or new noise models that are verified by field measurements [16][21][26][41][42][43][44][45][46][47][48]. The most important attributes of traffic influencing the noise are traffic flow, vehicle speed, and percentage of heavy vehicles, and these attributes are incorporated in established traffic noise emission models to a varying degree of detail [49][50][51][52]. Problems that emerge while modeling noise at roundabouts relate primarily to capturing the impact of their specific traffic flow conditions in the noise emission model. These specific traffic flow conditions are minimized start–stop operations and queuing, as well as the smaller average speed of approaching and passing traffic compared to the traditional intersections with traffic lights.

Depending on the way noise models account for traffic flow, the temporal and spatial variations in vehicle kinematics at intersections are more-or-less accurately captured. In static noise models, roads are divided into sections where traffic flow is considered smooth and homogeneous. These noise models usually include a propagation correction term for noise levels in the vicinity of an intersection, the value of which depends on the distance to the intersection [49][50]. Analytic noise models attempt to capture the impact of interrupted traffic on the average vehicle speed profile. They split each road section into subsections where vehicles are assumed to have a constant average speed and homogeneous traffic flow conditions [50]. Dynamic noise models or micro-simulation noise models are based on a dynamic traffic model, and as such can capture the specific traffic flow conditions in the vicinity of intersections [50][53][54][55][56][57][58].

The usability of each noise model depends on its reliability and accuracy. According to the previous studies, static models usually underestimate the noise levels compared to the analytic and dynamic noise models [50]. On the other hand, previous studies have shown that the increased complexity of a model that includes more physical phenomena and effects will not automatically produce better results in terms of model accuracy [51][59]. The optimal model is one in which the reliability of the result is harmonized with the available input data, and the costs and time required to create a noise model. Based on that, a static noise model RLS-90 was selected as a baseline for road traffic noise calculations conducted in the research presented in this paper. Previous research showed that modifications of the standard RLS-90 model can result in the reduction of differences between measured and calculated noise levels ranging from 1.0 to 2.8 dB(A) for streets and intersections [60][61]. However, the modifications concerning the position of noise sources showed to be too detailed and time-consuming when modeling traffic noise at roundabouts, especially roundabouts with more than one entry and exit lane. Another issue with these modifications is that they do not represent real traffic flow conditions at roundabouts, especially concerning the movement trajectories of vehicles negotiating these types of intersections.

3. Conclusions

Challenges that emerge in roundabout design are mostly related to space constrictions and the provision of appropriate deflection around the central island. This can result in inappropriate speed profiles on roundabouts that might reduce their potential as a noise abatement measure. Therefore, the impact on noise levels and its applicability as a traffic calming device should be investigated in the early design stage of a roundabout, by modeling road traffic noise levels. Established noise models used in noise prediction are either too complex for use in the preliminary design stage of roundabouts when the available input data is limited, or they do not even include intersection contribution to noise levels. At the same time, their creation can be rather time-consuming. This makes them less than optimal for use in noise predictions at roundabouts, as an optimal model is the one in which the reliability of the result is harmonized with the available input data, and the costs and time required to create a noise model.

In order to simplify the preparation procedure of the noise emission model and allow the simulation of the impact of the intersection on the noise situation in the early stages of roundabout design, the following results of the fastest path performance check could be utilized for noise calculations at suburban roundabouts with unsaturated traffic flow: vehicle movement trajectories (for the position of road traffic noise sources), and design speed (for noise calculations at roundabouts that are still in the design phase). These modifications result in a model that is close to the real world in terms of traffic flow conditions and enable modeling the influence of roundabout deflection on calculated noise levels. Also, these modifications should encourage the optimization of roundabout geometry in its preliminary design phase not only in terms of safety, but also in terms of its noise reduction capabilities, and/or emissions in general.

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