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Noise level in the vicinity of signalized roundabouts

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ABSTRACT

The analysis, assessment and estimation of noise levels in the vicinity of intersections is a more complex problem than a similar analysis for roads and streets. This is due to the varied geometry of the intersections, differences in the loads of individual movements, participation of heavy vehicles and mass transport vehicles, as well as the various types of traffic management and traffic control. This article analyses the influence of intersection type and traffic characteristics on the noise levels in the vicinity of classic channelized intersections with signalization, roundabouts and signalized roundabouts. Based on the conducted measurements, it has been established that, with comparable traffic parameters and the same distance from the geometric centre of the intersection, the L_{Aeq} value for signalized roundabouts is 2.5–10.8 dB higher in comparison to classic channelized intersections with signalization and 3.3–6.7 dB higher in relations to the analysed roundabout. Additionally the differences between L_{Aeq} levels at individual entries at the same signalized roundabouts may reach the value of approximately 4.5 dB. Such situation is influenced by differences in the intersection geometry, diameter of the intersection's central island, traffic flow type, traffic management at the entries and traffic volume, especially the amount and traffic movements of multiple axle heavy vehicles. These factors have been analysed in detail in relation to signalized roundabouts in this paper.

Introduction

Noise is a phenomenon which accompanies people in their everyday lives both in the workplace and places of leisure. Road traffic generates noise which is characterised by relatively varied levels and a large area of effect. Traffic on roads outside the cities moves with few hindrances. There are known methods of estimating noise in their vicinity, whose level depends on the traffic volume, vehicle speed, percentage of heavy vehicles, buses and motorcycles, longitudinal road slope and its surface characteristics (Quartieri et al., 2009; Garg and Maji, 2014). A definitely more complex issue is that of estimation and prediction of noise in the vicinity of intersections. Various geometrical solutions, differences in the traffic load of individual directions, percentage of heavy vehicles, participation of mass transport and pedestrians, varied traffic management and signalization, varied driving styles and lack of uninhibited traffic flow, all result in major difficulties in the prediction of noise levels in their vicinity. The present research work based mainly on theoretical and simulation analyses (Makarewicz and Golebiewski, 2007; Chevallier et al., 2009; Guarnaccia, 2010; Džambas et al., 2014; Lau et al., 2014; Covaciu et al., 2015) as well as the results of field measurements (Decký et al., 2012; Subramani et al., 2012; Golmohammadi et al., 2009; Abo-Qudais and Alhiary, 2004, 2007; Dragčević et al., 2006). These measurements show, that

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apart from the above mentioned factors, the type of intersection and traffic management also have a significant influence on the noise level. Recent research has shown also that traffic flow dynamics has an influence on urban soundscapes (De Coensel et al., 2005) and taking this influence into account contributes to better noise assessment (Can et al., 2009; Jahandar et al., 2012).

Taking into account the geometrical solutions of intersections, the following types are distinguished: classic intersections (without traffic islands), channelized intersections and channelized intersections with traffic moving around a central island. The traffic management criterion divides intersections into: intersections with no signalization, intersections with signalization and roundabouts.

A special type within the group of channelized intersections with a central island is a signalized roundabout where the traffic is being directed by signalization. This is a solution half way between a typical channelized intersection and an interchange, when capacity is concerned.

Intersection designs, apart from the assessment of capacity and traffic conditions, should also take into account these solutions which influence the noise level in their vicinity. In the case of complex channelized intersections, the noise sources are closer to the recipient, which results in the worsening of the acoustic climate in a larger area.

The existing traffic noise prediction models take the influence of intersections into account to various degrees. These models can be adjustment factors in the calculations of noise propagation (for example: German RLS-90 model (RLS, 1990) and the Dutch model (ASVV, 1989)). In the Scandinavian model Nord2000 (Jonasson and Storeheier, 2001) as well as in the Japanese ASJ RTN Model (Yoshihisa et al., 2004) the varying traffic dynamics on the intersections is taken into account in the emission models. In the American model FHWA TNM (Menge et al., 1998) and the French model NMPB Roads-96 (Certu, 1980) the influence of interrupted flow is taken into account by assigning various vehicle speeds to different parts of the intersection.

The influence of traffic volume on the noise level in the vicinity of intersections is determined mainly through function dependencies. In analytical models, the intersection is divided into individual sections with the assumption of homogenous and constant vehicle flow. Makarewicz et al. (1999) and Paoprayoon et al. (2005) have designed analytical noise emission models from traffic depending on the number of vehicles stopping and moving freely, with the influence of acceleration and breaking. The influence of signalization and the number of vehicles in line at the entrance to the intersection was determined by Stoilova and Stoilov (1998). Makarewicz and Golebiewski (2007) have suggested a model to determine the difference in noise levels in the vicinity of a classic intersection and a roundabout. This model does not take into account, however, the traffic dynamics. A statistical model based on the results of field measurements was designed by Abo-Qudais and Alhiary (2004, 2007). The model takes into account such traffic parameters as: volume, percentage of heavy vehicles, vehicle speed, slope of the entry of the intersection. A method was also given to calculate the noise levels in points along the intersection's entry depending on the distance of the observation point from the stopping vehicles.

There are also attempts to predict the noise in the vicinity of intersections based on computer microsimulation of traffic. Examples of such models are: M+P JARI (Suzuki et al., 2003), MOBILEE (De Coensel et al., 2005), TUNE (Goodman, 2001), ROTRANOMO (Volkmar, 2005) and SYMUBRUIT (Leclercq and Lelong, 2001). Modelling of the movement of individual vehicles (location, speed and acceleration) is used in models of sound emission and propagation. This modelling allows to determine the noise levels at specific distances from the intersection. Basing on the microsimulation model for various types of intersections De Coensel et al. (2006) have suggested an adjustment for the existing emission models.

The results of the present studies have shown that the noise levels in the vicinity of intersections depend on the geometry as well as the traffic characteristics and management on these intersections. The aim of this article is to compare the equivalent sound levels L_{Aeq} basing on field measurements in the vicinity of three types of intersections (a signalized roundabout, a classic channelized intersection with signalization, a roundabout). Due to the fact, that signalized roundabouts have been introduced quite recently and noise level prognosis models do not include the specificity of their functioning, this article will subject them to detailed analysis.

Signalized roundabouts – a general characteristic

A simple explanation is that a signalized roundabout is formed when two intersecting dual carriageways are split (Fig. 1a). An oval traffic island of 30–60 m in diameter is formed in the middle of such intersection with inner areas of accumulation for vehicles turning left with a capacity of 200–600 veh/h (Tracz and Gaca, 2010). In terms of traffic management such intersections are compared to a set of four intersections of one-way carriageways (so called sub-intersections) located on a small area (Fig. 1b). The practical capacity of the whole intersection depends on the geometry and traffic management and can reach 4000–8500 veh/h (Tracz and Chodur, 2012; Motylewicz and Gardziejczyk, 2012; DHV Group and Royal Haskoning, 2009).

In the calculations of the capacity of a signalized roundabout, each of the four sub-intersections, with their own traffic load at entry and traffic movement through the inner area of accumulation, can be analysed independently. For example, the total traffic volume on the sub-intersection A/B (Fig. 1b) is the 6 traffic streams from entries A, B and C: $A_{\text{r-turn}}$, A_{through}, $A_{\text{l-turn}}$, B_{through}, $B_{\text{l-turn}}$ and $C_{\text{l-turn}}$. The capacity of a signalized roundabout depends on the signalizing program, which directs the traffic at the entries and the inner areas of accumulation. Vehicles turning left at a specific phase of the signalizing program should take up space in the inner areas of accumulation and should not remain within the inner area of the intersection