



MICRO ROUNDABOUTS AS A ROAD TRAFFIC NOISE MITIGATION MEASURE

Saša Ahac, Maja Ahac, Dominik Burkovac

University of Zagreb, Faculty of Civil Engineering, Croatia

Abstract

Micro roundabouts are a traffic calming measure used on residential streets as an alternative to priority intersections, signalised intersections, and standard roundabouts. A basic element of a micro roundabout is a circular central island inserted into the existing intersection footprint, which deflects vehicles and reduces their average speed from 5 to 12 km/h. At the same time, micro roundabouts reduce driver start-stop operations, meeting the requirements for an effective noise abatement measure. The impact of a micro roundabout on road traffic noise levels and its applicability as a noise abatement measure can be investigated by modelling noise levels in the early design stage. Namely, previous research has shown that vehicle movement trajectories obtained during the fastest path performance check can serve as road traffic noise sources for the static noise model. The goal of the research presented in this paper was to define the micro roundabouts' central island diameter that provides road traffic noise reduction for specific intersection design configurations.

Keywords: static noise model, vehicle movement trajectories, fastest path, relative speed, central island design

1 Introduction

Road traffic noise levels can be reduced by lowering vehicle speed and ensuring a smooth driving pattern [1]. Achieving this often requires modifications to the physical road layout. In urban areas, to enable the abovementioned requirements, several road traffic noise mitigation solutions are used. These are the introduction of road humps, road width narrowing, and the adaptation of standard intersections into modern roundabouts [2, 3]. Previous research has shown that road humps can reduce noise by 1 to 2 dB(A), while road width narrowing can reduce noise by 1 to 3 dB(A) [4]. Modern roundabouts, as traffic calming devices on which operating speed depends on the achieved deflection around the central island [5, 6], and devices that can carry smooth traffic flow by minimising the start–stop operations of drivers, can reduce the noise from 1 to up to 4 dB(A) [3, 4].

Micro roundabouts, also known as traffic-calming circles or neighbourhood-calming circles, are an alternative type of modern roundabouts. In general, alternative types of roundabouts differ from the standard ones in geometric features and elements, as they are adapted to local spatial requirements and traffic conditions. Specifically, micro roundabouts are created by inserting a small central island into the existing intersection footprint. This element forces car drivers to slow down, simultaneously allowing the unobstructed passage of long vehicles. As it does not require significant infrastructural changes and preserves the existing appearance of the urban space, it allows for quick user adaptation and easy integration into existing traffic flows. Therefore, micro roundabouts are applied to increase traffic safety and reduce vehicle speeds in areas with moderate traffic loads, such as residential areas, school zones, and local streets [7-9].

The research presented in this paper was motivated by the need to understand whether micro roundabouts can also be an efficient road traffic noise mitigation measure. Research described in [10] has shown that vehicle movement trajectories obtained during the roundabouts' fastest path performance check can serve as road traffic noise sources for the static noise model. This investigation was conducted on 14 micro roundabout schemes with varying design elements, designed via Autodesk AutoCAD 2021 software. It included: (1) the determination of the vehicle path for the straight passage of personal vehicles and the deflection provided by the micro roundabouts' central island, (2) the determination of passenger vehicle speed through the fastest path analysis following a procedure for standard roundabouts that is described in [11], and (3) road traffic noise modelling by means of LimA software and modified RLS-90 static noise model. The results of road traffic noise modelling were compared to those obtained for the standard unsignalized intersection. The aim was to determine the central island diameter of micro roundabouts that effectively reduce road traffic noise for specific intersection designs.

2 Methodology

The research was conducted on 14 micro roundabout schemes with varying driving lane widths (a), curb radii (R), and central island diameters (D), given in table 1. These values are in line with the results of previous research described in [12]. They showed that the optimal design element combinations for micro roundabouts in the City of Zagreb are those that result in design speeds around the central island between 20 and 25 km/h for intersections in residential areas with the speed limit of 30 km/h. These combinations are listed in table 1.

Table 1 Analysed micro roundabouts' design elements

a [m]	R [m]	D [m], $\Delta D = 0.5$ m
3.25	7	4.0–5.5
	6	3.5–4.5
	5	3.5–4.0
3.0	7	3.5–5.0
	6	3.5

The selected increments for lane widths (a), curb radii (R), and central island diameters (D) were chosen to capture the dispersion of the results and to create a sample that is simultaneously representative, manageable, and easy to present. The intersection approach leg axes for all schemes intersect at the centre of the central island. For these roundabout schemes, driving speed estimations were conducted, noise models were defined, and noise reduction was estimated and compared to the standard intersection, as described in the following chapters.

2.1 Driving speed estimations

The expected driving speed was estimated through the fastest path analyses conducted on micro roundabout schemes created in Autodesk AutoCAD 2021 software. The fastest path analysis consisted of the following steps. In the first step, the fastest paths were drawn using cubic splines, following the instructions described by [11]. Following the instructions given in [13], the designed cubic splines were tangent with minimum clearances of 1 m from the painted line and 1.5 m from the curb and the central island (figure 1).

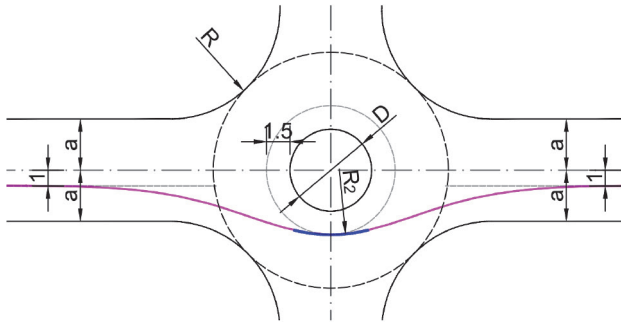


Figure 1 Micro roundabout's elements and fastest paths for through movement

In the second step, the path radii located on the fastest path were measured. In the third and final step, estimations of vehicle speed were conducted for path radius based on the following speed–radius relationship, given in [11]:

$$V_2 = \sqrt{127 \cdot R_2 \cdot (f + e)} \quad (1)$$

where V_2 [km/h] is the predicted design speed on the fastest path around the central island, R_2 [m] is the path radius, f [-] is the side friction factor, and e [-] is superelevation (assumed to be 0.025) [12, 13].

2.2 Noise modelling

To define the micro roundabouts' central island diameter that provides road traffic noise reduction for specific intersection design configurations, noise levels modelled for the analysed micro roundabouts were compared with those modelled for the standard unsignalized intersection (figures 2 and 3). Noise modelling was conducted via specialised software LimA, and a modified static noise model RLS-90 [14]. Applied RLS-90 model modifications were as follows.

- Periods “day”, “night”, and “evening” were defined in accordance with the Environmental Noise Directive (END) [15]: “day” lasted from 7:00 to 19:00, “evening” lasted from 19:00 to 23:00, and “night” lasted from 23:00 to 7:00.
- Noise sources were positioned on the movement trajectories derived from the roundabout fastest path performance check for micro roundabouts (figure 2) and at the centre of the approaches for one standard intersection (figure 3), 0.5 m above the road surface.
- Data on road traffic flow was based on Tool 2.5 “No traffic flow data available” given in [16]: recommended default values for collecting roads were used, i.e. number of vehicles was 700 for “day” (or 58 veh/h), 200 for “evening” (or 50 veh/h), and 100 for “night” (or 12 veh/h).
- Data on road traffic composition was based on Tool 4.5 “No heavy vehicle data available” given in [16]: recommended default values for collecting roads were used, i.e., percentage of heavy vehicles was 10% for “day”, 6% for “evening”, and 3% for “night”.
- Vehicle speed was defined based on the speed–radius relationship given in [11] for the path around the central island on the analysed micro roundabouts and set to 30 km/h for the standard intersection and the micro roundabout approaches, based on the Tool 3.5 “No speed data” given in [16] (figure 2).
- The addition for the increased effect of intersections was set to 0.
- Immision points were placed 7.5 meters from the vehicle trajectory and 1.2 m above ground (figures 2 and 3).

The abovementioned modifications simplified the preparation of the noise model, resulted in a model closer to the real-world in terms of vehicle speed, and include the influence of roundabout deflection on calculated noise levels [10]. Noise model elements for the analysed micro roundabouts and a standard intersection are presented in figures 2 and 3. For this investigation, noise receptors were placed at the centres of the intersections, 7.5 m from the noise source, and at a height of 1.2 m above ground level.

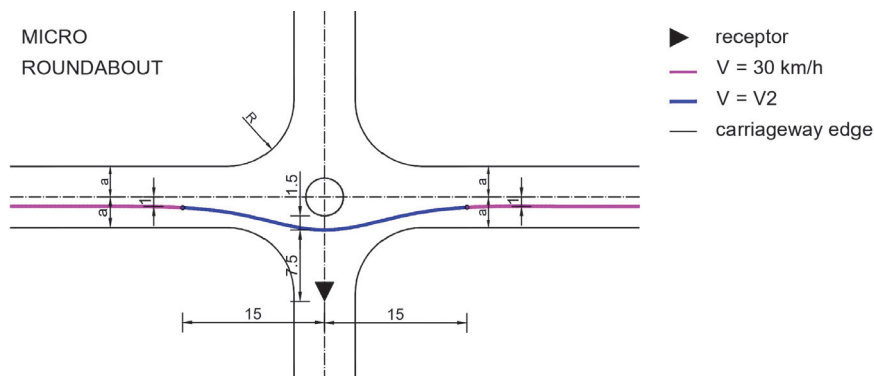


Figure 2 Noise model elements for micro roundabouts

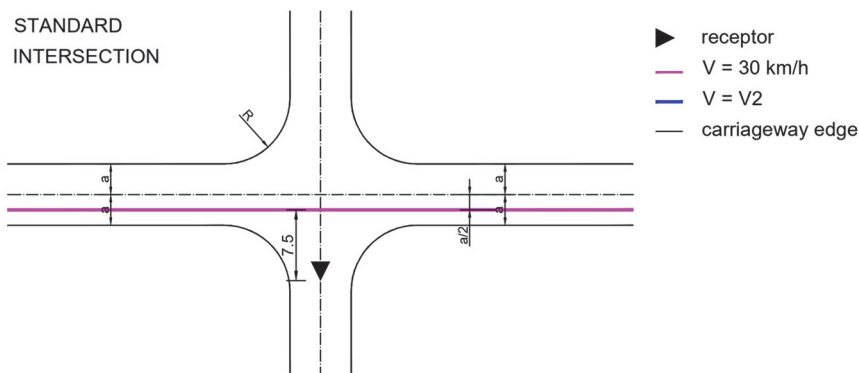


Figure 3 Noise model elements for standard intersection

3 Results

The estimated driving speed around the central islands of the analysed micro roundabouts is given in table 2. Its values range from 20 to 25 km/h, resulting in 10 to 5 km/h reduction in vehicle speed, assuming that the approach speed is set to 30 km/h. Predicted noise levels for the standard intersection were 57 dB(A) for period “day”, and 47.6 dB(A) for period “night”. Noise modelling results for micro roundabouts were compared with these levels to determine the achieved noise level reductions at 7.5 m from the noise source and at a height of 1.2 m above ground. The results of the noise levels comparison, ΔL_{day} and ΔL_{night} , are given in table 2. The achieved noise reductions were between 1.5 and 2.2 dB(A) for the “day” period and between 1.3 and 1.8 dB(A) for the “night” period. To further visualise the potential noise reduction achieved by replacing a standard unsignalized intersection with a micro roundabout, noise models that incorporated noise sources for straight vehicle passages were created for the standard intersection and for micro roundabout No. 9 (table 2).

These models were used to generate isophones at a height of 1.2 m above ground level for the period “day”, shown in figure 4, where continuous lines represent isophones for the standard intersection, while dashed lines are isophones for the micro roundabout. The most significant reduction in noise levels occurs at the centre of the intersection. In a standard intersection, noise levels exceeding 65 dB(A) affect an area of 370 m². In contrast, on the micro roundabout, these noise levels only impact a 90 m² area.

Table 2 Driving speed and noise modelling results

No.	a [m]	R [m]	D [m]	R ₂ [m]	V ₂ [km/h]	ΔL_{day} [dB(A)]	ΔL_{night} [dB(A)]
1	3.25	7	4.0	17	25	1.5	1.3
2			4.5	15	24	1.7	1.5
3			5.0	12	22	2.0	1.7
4			5.5	11	21	2.2	1.8
5	6	6	3.5	17	25	1.5	1.3
6			4.0	13	23	1.8	1.5
7			4.5	12	22	2.0	1.7
8	5	5	3.5	12	22	2.0	1.7
9			4.0	10	20	2.3	1.8
10	3.0	7	3.5	15	24	1.7	1.5
11			4.0	13	23	1.8	1.5
12			4.5	12	22	2.0	1.7
13			5.0	10	20	2.3	1.8
14	6	6	3.5	11	21	2.2	1.8

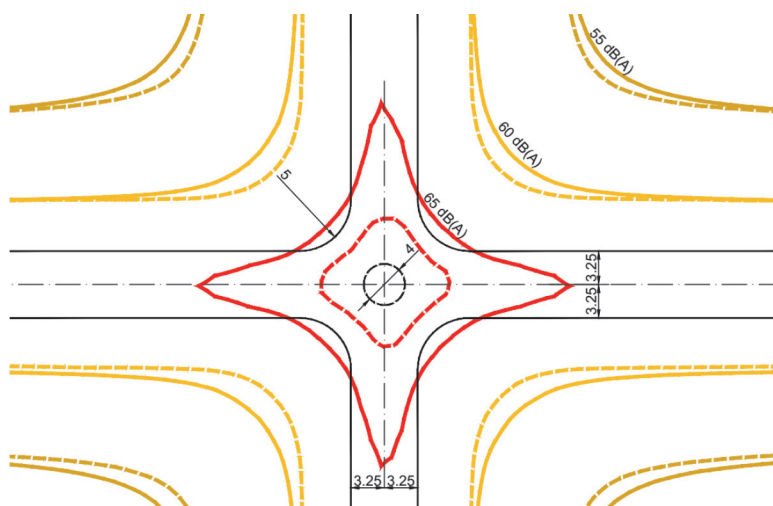


Figure 4 Noise reduction achieved by replacing a standard intersection (continuous isophone) with a micro roundabout (dashed isophone)

4 Conclusion

Previous research has shown that converting standard intersections to modern roundabouts can reduce road traffic noise up to 4 dB(A). Unfortunately, due to the spatial and economic requirements, as well as traffic conditions, their application is usually impossible in densely built residential areas. In these locations, micro roundabouts can be used, as they do not require significant infrastructural changes and preserve the existing appearance of the urban space, allowing quicker user adaptation and easy integration into existing traffic flows.

The research presented in this paper confirms that micro roundabouts can be a useful road traffic noise mitigation measure, as they lower the predicted road traffic noise levels by 1.5 to 2.3 dB(A). As the reduction in noise levels achieved by implementing micro roundabouts is lower than that of standard modern roundabouts, they should be combined with the use of noise-reducing pavements. This could lead to a significant reduction in overall noise levels, as previous research indicates that combinations of quiet pavements and speed reduction measures can reduce noise by approximately 3 to 8 dB(A) [3]. Additionally, micro roundabouts positively impact traffic safety, promote smoother driving patterns, and prevent vehicles from coming to a complete stop, which can cause increased noise due to acceleration in lower gears. Another benefit of micro roundabouts is that they do not alter the road height like road humps—a feature that usually leads to an increase in road traffic noise levels [3].

A key limitation of the analysis described in this paper is the use of the fastest path methodology for vehicle speed prediction. This methodology is conventionally employed for standard modern roundabouts with splitter islands and entry and exit radii. Therefore, the reliability of predicted speed values for micro roundabout schemes requires validation using empirical speed measurements. Additionally, the effects of vehicle deceleration and acceleration on noise levels at the micro roundabout legs were not modelled. Subsequent research will extend the analysis to include real-world micro roundabouts in the City of Zagreb's residential areas and the comparison of the results from a static and a dynamic noise model.

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