Abstract: Mini-roundabouts are small roundabouts with a fully traversable central island. They are most commonly used within low-speed urban environments (or settlements) with average operating speeds of 50 km/h or less. They can be very useful in such environments where conventional (one-lane) roundabout (or some other type of intersections) could not be implemented (due to different reasons). In Slovenia we implemented the first mini roundabout in the year 2002. Since then we have build’s more than 20 mini roundabouts across the country. We have actively monitored the processes of implementing mini roundabouts from the beginning, from the first implemented roundabouts to today. This paper presents and analyses main experiences we have gained during this time.

Keywords: mini roundabouts, design elements of mini roundabouts, traffic safety

1. INTRODUCTION

In the Republic of Slovenia, modern roundabouts have become more and more appealing for both designers and investors, especially over the last 20 years. Our deep interest in modern roundabouts started two decades ago, before which Slovenia had practically no significant experiences with roundabouts and their advantages as traffic control systems. After 20 years since the first wave of modern roundabouts in Slovenia, there are currently more than 500 roundabouts (Mini roundabouts, Single-lane roundabouts, Multi-lane roundabouts and Turbo roundabouts) installed all over the country. It is admirable that both the roundabouts’ designers and contractors have carried out their work professionally and with a high degree of care and skill when considering that there was (a) a chronic lack of professional literature on roundabouts (b) an excess of professional literature, manuals, and guidelines from other countries (c) a lack of our own guidelines for roundabouts (d) no data regarding the number as well as the consequences of local traffic accidents. The process of introducing roundabouts into the Republic of Slovenia was spearheaded by a number of stakeholders. The key stakeholders included the traffic police, the media, and driving schools. The media especially played an important role by providing information to the largest number of users namely; PCU drivers, pedestrians, as well as cyclists. After the initial enthusiasm over the introduction of the first few roundabouts into Slovenia had subsided, questions concerning the justification of their installations and actual traffic safety surfaced. When considering that roundabouts in Slovenia were at the time a new phenomenon (with the exception of a few earlier examples), the concerns raised were completely understandable. Furthermore, there was no assurance that
roundabouts in Slovenia would prove themselves appropriate, as they had abroad (in Holland, Germany and the United Kingdom). Today in Slovenia we have roundabouts of varying types; mini roundabouts, standard one-lane roundabouts, two and three-lane roundabouts, double roundabouts, assembled roundabouts, turbo-roundabouts and signalized turbo-roundabout, of which approx. 70% are on state roads, and 30% on municipality and private roads [3].

Modern concept of a mini-roundabout had already been introduced in the UK the by the early 1970’s. Mini roundabouts are well-known as roundabout design solutions for the means of improving capacity and reducing delays at existing junctions where there is limited space for introducing other forms of control (or a typical one lane roundabout). It is worth mentioning that mini roundabouts today are also recognized as traffic calming measure within build-up areas.

2. PLANNING AND DESIGN OF MINI ROUNDABOUTS

When we reconstruct “classical intersection” into mini roundabout we could achieved many positive aspects: mini-roundabouts are relatively inexpensive because they typically require minimal additional pavements at the intersecting roads and minor widening at the corner curbs. They are mostly recommended when there is insufficient right-of-way to accommodate the design vehicle with a traditional single-lane roundabout. Because they are small, mini-roundabouts are perceived as pedestrian-friendly with short crossing distances and very low vehicle speeds on approaches and exits. A fully traversable central island is provided to accommodate large vehicles and serves one of the distinguishing features of a mini-roundabout. The mini-roundabout is designed to accommodate passenger cars without requiring them to traverse over the central island. The overall design of a mini-roundabout should align vehicles at entry to guide drivers to the intended path and minimize running over of the central island to the extent possible.

2.1. What is mini roundabout?

Mini-roundabouts are small roundabouts with a fully traversable central island. They are most commonly used within low-speed urban environments with average operating speeds of 50 km/h or less. They can be useful in such environments where conventional roundabout design is precluded by right-of-way constraints. In retrofit applications, mini-roundabouts are relatively inexpensive because they typically require minimal additional pavements at the intersecting roads and minor widening at the corner curbs. They are mostly recommended when there is insufficient right-of-way to accommodate the design vehicle with a traditional single-lane roundabout. Because they are small, mini-roundabouts are perceived as pedestrian-friendly with short crossing distances and very low vehicle speeds on approaches and exits. A fully traversable central island is provided to accommodate large vehicles and serves one of the distinguishing features of a mini-roundabout. The mini-roundabout is designed to accommodate passenger cars without requiring them to traverse over the central island. The overall design of a mini-roundabout should align vehicles at entry to guide drivers to the intended path and minimize running over of the central island to the extent possible [1].

In Slovenia we implemented the first mini roundabout in the year 2002. Since then we have build’s more than 20 mini roundabouts across the country. Typical Slovenian urban mini roundabout is presented on Fig. 1. It has to be mentioned that in some cases there is a misunderstanding about term "mini-roundabout": the term “mini-roundabout” derive (primarily) from fully traversable central island and not from the size of one-lane roundabout. Some cases of small one-lane roundabouts (not mini roundabouts!) are shown in Fig. 2.
2.2. Where to construct mini roundabout?

When deciding to construct a mini roundabout it is necessary to consider the characteristics of the existing road network in the surrounding area (e.g. existing types/designs of intersections, etc.), the existing ways of traffic routing and the "expectations of users", i.e. traffic participants.

Mini roundabouts can be constructed instead of the existing "classic" three- and four-lane intersections, which can lead to a reduction in the number of traffic accidents, a reduction in delays and queues at the intersection, as well as reduction in the speeds of motor vehicles (as an individual traffic calming measure or combined with other traffic calming measures).

Mini roundabouts can be constructed only on those roads within settlements where the maximum allowed speed is 50 km/h (or lower). In addition, the measured speed \( V_{85} \) on joining roads of a mini roundabout (within the distance of 70 m from the mini roundabout) is lower than 50 km/h. If the measured speed \( V_{85} \) on joining roads exceeds 50 km/h, it is necessary to construct a mini roundabout together with other traffic calming devices and traffic calming measures.

A mini roundabout is a good solution when reconstructing existing intersections (and as a "rehabilitation measure") within different environments – built-up areas, residential areas, business areas or shopping areas. Mini roundabouts are also suitable when reconstructing existing intersections [2]:

- Intersections of "irregular shape" such as, e.g. Intersections in the shape of the letters "Y", "K", "A" and "X";
- Intersections in the shape of letters "F" and "H" (two consecutive "T" intersections within a short distance);
- When the traffic loads are approximately equal in the main and minor traffic routes;
- Where the installation of traffic-lights is not justified, but the capacity of an intersection with no traffic-lights is exceeded;
- When the main traffic route is unsuitable in relation to the existing intersection geometry.
Mini roundabouts are not the most suitable solution when the share of large motor vehicles in the main route is large (freight vehicles and/or buses). The construction of mini roundabouts is not recommended on significant public transport lines or at industrial/manufacturing zones, etc.

2.3. Design elements of mini roundabout

Designing a mini roundabout is done following steps - similar to those when designing a "classic" one-lane roundabout. The designing is carried out in the following steps [2]:

- Selection of outer diameter;
- Selection of width of the circular carriageway;
- Selection / adjustment of width of the carriageway in front of the roundabout;
- Define the width of the roundabout inbound point;
- Flare of the inbound point;
- Inbound radius;
- Outbound radius;
- Inbound angle;
- Width of the roundabout outbound point;
- Horizontal and vertical routing;
- Cross slopes and drainage;
- Other elements;
- Visibility;
- Equipment;
- Landscaping.

2.4. Additional steps at the process of mini roundabout design

The following should also be taken into consideration when designing mini roundabouts [2]:

- Visibility and recognition of the mini roundabout: For mini roundabouts, it is important that drivers recognize the intersection in a timely manner and drive through it correctly. They must be designed in such a way that they enable vehicles to slow down in a timely manner, to stop if needed, and then continue driving safely. Drivers must be discouraged from drive improperly through the implementation of the right dimensions;
- The speed of vehicles: mini roundabouts are not designed for high speeds since – in terms of their elements - they consequently slow down traffic. The expected speed of vehicles is up to 25 km/h;
- Road characteristics;
- AADT;
- Number of branches;
- Traffic structure;
- Other participants in traffic (pedestrians, cyclists, public transport);
- Connection roads, noise and vibrations.

3. SPECIAL DESIGN ELEMENTS OF URBAN MINI ROUNDBOUNDS

According to our experiences we could expose some of the special elements, which occur at process of urban mini roundabout design.
3.1. Splitter islands design

Splitter islands can be constructed in the following way:

- In de-levelled form / raised splitter island: edged splitter islands, where the splitter island must be at least 1.2 m wide at its narrowest point - for installation of traffic signs (Fig. 3);
- Splitter island constructed in the same way as the central island – as a mountable cobblestone island; the edge de-levelled by 3 cm (Fig. 4);
- Splitter island made only with horizontal road signs / pavement markings (Fig. 5).

According to our experiences it is desirous to construct - if it is possible - raised splitter islands (at least) at main traffic directions. With such solutions we could separate traffic moving in opposite directions, deflect entering traffic, prevent overtaking in the area of mini-roundabout and to provide opportunities for pedestrians to cross in two stages.

3.2. Requirements of public transport

In some cases it is necessary to include some special requirements of public transport (buses) into mini roundabout design process. This is especially necessary at locations, where we already have special lane (bus lane) for public transport. In that cases we lead buses on their lane (bus lane) also at mini roundabout (Fig. 6).
3.3. Traffic calming measures at mini roundabouts

If the speeds of motor vehicles on main traffic direction exceeded the expected value and/or there should be some additional protection for pedestrians/cyclists, it is reasonable to add traffic calming devices/measures at the location of mini roundabout. Traffic calming devices/measures could be in the form of warning devices (for example, additional warning lights, optical (white) strips) or speed reduction measures (for example, speed tables in combination with pedestrian/cyclist crossing, Fig. 7).

![Speed table with pedestrian and cyclist crossing as traffic calming measure before entering in mini roundabout (Maribor)](image)

Fig. 7. Speed table with pedestrian and cyclist crossing as traffic calming measure before entering in mini roundabout (Maribor)

4. SLOVENIAN EXPERIENCES WITH MINI ROUNDABOUTS

In last 10 years we (Centre for traffic infrastructure at Faculty for Civil Engineering, University of Maribor, head of chair prof. dr. Tomaž Tollazzi) were actively involved in process of planning, design and also monitoring construction of mini roundabouts across Slovenia (for example, Fig. 8). Some of our main findings are highlighted below.

![Design project and implemented solution of mini roundabout (Sl. Bistrica)](image)

Fig. 8. Design project and implemented solution of mini roundabout (Sl. Bistrica)

3.1. Traffic safety of Slovenian mini roundabouts

Based on the results of a traffic safety analysis of mini roundabouts constructed in Slovenia, we observed traffic accidents that had occurred at 11 mini roundabouts 3 years prior to the
reconstruction of intersections to the mini roundabouts and 3 years after them. It can be seen (Fig. 9) that the number of traffic accidents decreased by approximately 7 times.

Main data's:
- we analyzed 11 mini roundabouts, which were built in the last 10 years in Slovenia;
- we performed B-A analysis of traffic accidents (TA). Period - 3 years before, 3 years after reconstruction;
- only Police recorded accidents were included;
- in 11 mini roundabouts there was 15 TA before, only 2 TA after the reconstructions.

3.2. Some deficiencies of implemented mini roundabouts

Although implemented mini roundabouts (in most cases) fulfil expectations we could also find some deficiencies in - it has to be said rare - implemented mini roundabouts in Slovenia. Those deficiencies refer to:
- unsuitable splitter islands construction (unsuitable design, construction - in correlation with posted traffic signs, Fig. 10);
- road markings (visibility and maintenance of road markings);
- visibility of central island (not just (with road markings) painted central island, better solution is mountable cobblestone island; the edge de-levelled by 3 cm);
- unsuitable width of driving lanes (before mini roundabout or inadequate widening of driving lanes before entering the mini roundabout);
- unsuitable design and construction (in some cases we notice lack of knowledge about mini roundabout design and construction);
- traffic rules violations (it is in connection with inadequate mini roundabout design and construction, especially splitter islands construction, Fig. 11).

![Fig. 9. Average number of traffic accidents in single mini roundabout before and after reconstructions of intersections to mini roundabouts](image)
4. CONCLUSIONS

This article describes and analyses the Slovenian experience with mini roundabouts. Unlike other types of modern roundabouts that we have had in Slovenia for more than 20 years, the first mini roundabout was constructed in 2002. Notwithstanding the relatively short period of time, during that period several mini roundabouts were constructed in Slovenia.

We have actively monitored the processes of implementing mini roundabouts from the beginning, from the first implemented roundabouts to today. This paper presents and analyses the experiences we have gained during this time.

Some of the characteristics of mini roundabouts differ from “normal” single lane roundabouts. Based on our experience gained, it can be concluded that at during mini roundabouts design it is very important to choose the proper design parameters, the design and construction elements should be adjusted, and the splitter island’s design is especially important from the driving lines point of view.

According to our findings from analyses of implemented mini roundabouts on Slovenian roads we could conclude that mini roundabouts are recognized as good solutions, we gained positive driver’s opinion and we didn’t notice any (major) problems regarding traffic safety aspects. Therefore we could conclude that in Slovenia we have (in general) very good experiences with mini roundabouts.

From our experiences with mini roundabouts and assembled roundabout’s implementations, which we have obtained over the last 10 years, we already prepared a proposal for the updated version of a Slovenian technical specification about roundabouts design.

5. REFERENCES