

LITHUANIAN EXPERIENCE OF IMPLEMENTATION OF ROUNDABOUTS: THE RESEARCH OF ACCIDENTS, OPERATION AND EFFICIENCY

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Abstract. In the past decade, Lithuania had one of the worst statistics in road traffic safety in comparison to other European Union countries. The implementation of roundabouts in most dangerous intersections was a key element that brought about many promising and positive results in this field. Since 1998, when the first modern roundabout was built in Lithuania, around 40 more of these engineering structures have been constructed. Although it has been justified as a safe solution; there is still considerable scope for improvement. For this reason the data of accidents, design mistakes, construction flaws and operation problems have been researched and collected. This article concentrates on improving characteristics of roundabouts, making them more adequate for Lithuanian weather conditions and driving mentality.

Keywords: road traffic safety, modern roundabouts, accidents, operation of roundabouts, roundabouts efficiency, Turbo roundabouts.

1. Accident situation in Lithuania

Comparing 2009 with 2008, in Lithuania the number of people killed in traffic accidents declined by more than 26%. In 2009 there were 3844 fatal traffic accidents on the roads and streets of Lithuania, i.e. 29.4% less than in 2008. 368 people were killed - 26.3% less, 4,484 people were injured - 23.2% less than in 2008 (Fig 1).

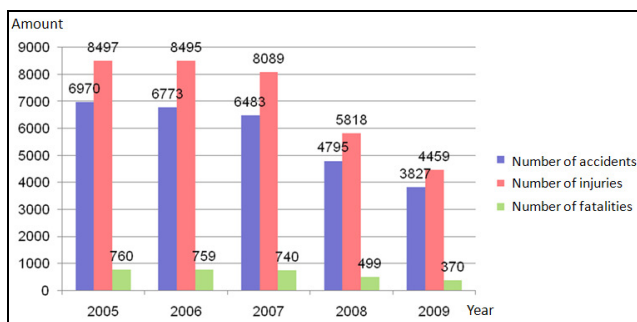


Fig 1. Accident rate in Lithuania 2005 – 2009

The financial damage caused by accidents, which killed or wounded people in 2009 compared with 2008 decreased by more than 700 million Litass (around 200 Euros). The largest impact was made by introducing modern engineering traffic safety improving measures,

active educational practice and increased liability for failure to comply with road traffic enforcement.

The most common accidents on Lithuanian roads are collisions of vehicles, and collisions between vehicles and pedestrians. These types of traffic accidents together account for more than 60% of the fatalities on the roads. More than 34% of collisions between vehicles and pedestrians occur at intersections (Fig 2).

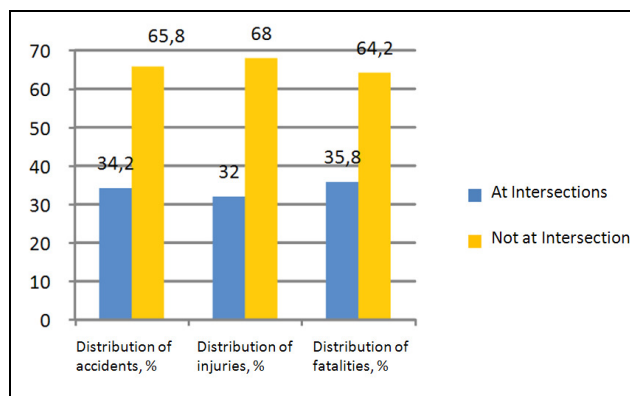


Fig 2. The distribution of accidents, killed and injured in junctions and not in junctions

The infrastructure of Lithuanian cities and roads have been being built for many years, but because of the

rapidly changing pace of lifestyle and the increase of the number of motor vehicles on the roads, many infrastructure solutions no longer meets present requirements. This causes not only increasing number of accidents, but also the growing amount of emission and vehicle traffic. Extremely high levels of pollution are emitted when vehicles move through the intersections. Immediate solutions must be found for all above mentioned problems in junctions. One of the modern and most efficient accident and emission reduction technique at intersections is installation of small roundabouts.

2. Modern roundabout in the world and in Lithuania

Modern roundabouts were discovered and begun to be built around 1960 in United Kingdom, United States followed its successful experience. Between 1980 and 1990 number of tests of capacity, accident rates and emission were executed in different countries. The positive results in 1982 started the massive building of roundabouts in Germany, Denmark, Holland, Sweden, Norway, France and other countries. Many years of practice has confirmed that this is one of the most proven types of at grade intersections, that is why as well as in most economically powerful and in developing countries this type of roundabout is installed more and more every year (SETRA, 1992). Netherlands alone, which's area, is 1/3 less than that of Lithuania has nearly 4,000 modern roundabouts.

Although in many countries the practice has shown that this type of intersection is the most proven at grade intersection type, Lithuania did not adopt this practice and this type of intersection has not been implemented. However, after regaining independence, a number of factors have changed: levels of motorization began to grow rapidly which caused growing traffic volume and accident rate. It was necessary to find solutions to improve the situation. One of the first modern roundabouts was built at the entrance to Kedainiai town in 1998. This intersection until its reconstruction was a known "black spot", where on average one person was killed and three injury accidents occurred annually. Since 1999 there were only one or two modern roundabouts built annually in Lithuania. However, as already mentioned, in 2004 Lithuania committed to reduce the number of fatal accidents by half by 2010 and started using proven experience of Western countries in reducing the accident rate. One of the solutions was the construction of modern roundabouts. This type of intersection started rapidly being built since 2005. Currently, Lithuania has 27 modern roundabouts, and there will be built 40 more in near future.

3. Modern roundabout's advantages compared with old-style circular intersection

Modern and old-style circular roundabouts vary in size and geometrical parameters. Modern roundabouts are much smaller and more compact. It is also different in geometrical parameters: entry and exit pathway, lane

widths and so on. In modern roundabouts the streets, entering the circle, blend in a steeper angle, as in the old-style – streets blend to the circle with an acute angle (Fig 3) (PIARC, 2003). When the axis is blend in steeper angle, the driver better sees the vehicles approaching him in the circle, also it ensures lower speed when entering the intersection, etc.

Less land is needed to install such intersections, which is very important, especially in the cities. Old-style intersection's entrances and exits lanes are very wide, more than vehicle can enter circle at the same time, which leads to dangerous situations because the drivers lose control of driving priority. Moreover, the large diameter and a smooth entry into the old-style roundabout allow reaching high speeds, sometimes even up to 70 km/h. It affects not only the safety, but also the capacity of the intersection: when one vehicle travels at a high speed other drivers are simply afraid to enter the intersection. Not to mention the fact that the consequences of a high speed accident are very painful.

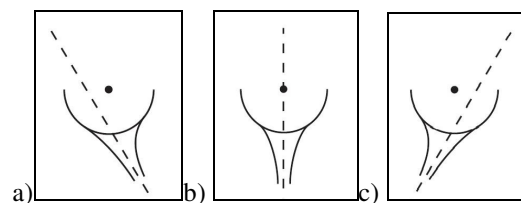


Fig 3. The geometry of roundabouts: acceptable (a), ideal (b), wrong (c)

4. Modern intersection's advantages compared with other types of junction

Simple triangular junction has 9 so-called conflict points, where traffic flows intersect. A simple four leg intersection (regardless of whether the traffic is controlled by lights or signs) has 32 such points. A four leg modern roundabout with one entrance (exit) and one circulating lane has only eight conflict points (Fig 4). A modern triangular roundabout has only six points of conflict. The reduced number of conflict points results in lower probability of accidents ("Modern roundabouts 101", 2000).

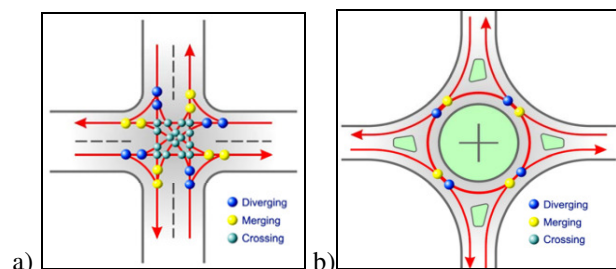


Fig 4. The number of conflict points in at grade junctions. Four leg junction has 32 conflict points (a) and roundabout has 8 conflict points (b)

As already mentioned, the driving speed in a modern roundabout is relatively low. If the intersection is designed properly, the central island radius should be be-

tween 5 m and 30 m, and all the outer diameter can vary from 16 meters to 45 meters. If the roundabout has two traffic lanes, its diameter can reach 60 m (while the old-style circular intersections ranged in diameter from 70 to 300 years). Numerous studies have shown that modern roundabout's optimum speed should not exceed 16-30 km/h. If the accident happens driving in indicated speed, it would normally be only technical - there would be no injury and fatality. Meanwhile, there are no physical barriers in simple three or four leg giveway and signalized intersections to make drivers slow down, even when the red light is on.

The above mentioned 27 intersections have been built mainly in high accident rate places where "black spots" have formed. To determine the impact of the three or four leg intersections' reconstruction to roundabouts, analysis of 14 roundabouts built in 2001-2007 in residential areas was carried. Prior to the roundabout installation an average of 1-5 fatal accidents occurred within four years. The most common accidents were collision between vehicles or vehicles and pedestrians.

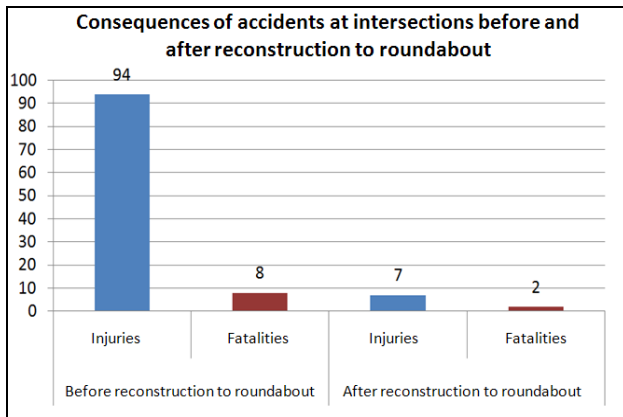


Fig 5. Accidents results in junctions before and after reconstruction to roundabouts

Table 1. Accidents rate in junctions before and after reconstruction to roundabouts

Nr.	Year built	Town	Traffic accidents	
			4 years before installation	After installation
1	2008	Krosna	-	-
2	2008	Krosna	-	-
3	2006	Jonava	2005 m. - 3 collisions	-
4	2007	Kėdainiai	2005 m. - 2 collisions 1 with bicyclist	-
5	2004	Ukmergė	2003 m. - 1 hitting pedestrian	-
6	2006	Kėdainiai	2006 m. - 2 collisions, 2005 - 1 collisions	-
7	2007	near Kuršėnai	2007 m. - 2 collisions, 2007 m. - hitting pedestrian	-
8	2006	Ukmergė	2003 m. - 3 collisions 2004 m. - 2 collisions 2005 m. - 1 collision 2006 m. - 3 collisions 2006 m. - 1 collision with bicyclist	-

End of Table 1

9	2002	near Kupiškis	-	-
10	2006	Šilalė	2005 m. - collision 2004 m. - collision	-
11	2006	Laukuva	-	-
12	2007	near Utena	2004 m. - 1 collision 2007 m. - 1 collision	-
13	2006	near Utena	2005 m. - hitting pedestrian 2005 m. - collision	-
14	2006	Vilnius	2003 m. - hitting pedestrian	-

Another very important parameter of roundabout - junction's capacity. While in Lithuania a general perception still is that the roundabouts are disadvantageous, accidental and impermeable, the perception is not true - the problem is the old-style circular intersections. Old-style large-diameter roundabouts because of their large diameter, high speed and not suitable geometric parameters were not conducive, led to chaotic situations in which drivers behaved improperly. However, this does not apply to modern roundabouts. One-lane roundabout's capacity is about 15000 - 25000 vehicles per day (or 1500 - 2500 vehicles per hour) (Fig 6 and Fig7) (PIARC, 2003).

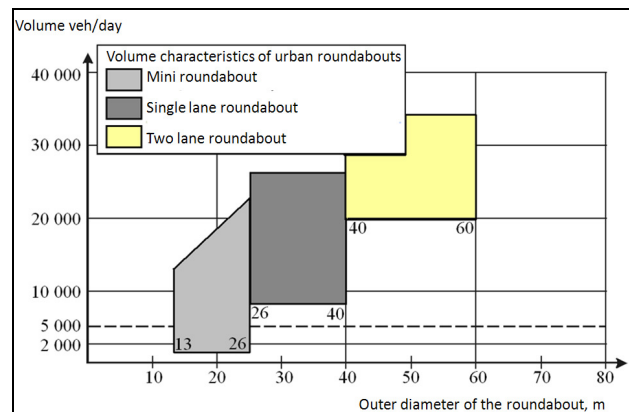


Fig 6. The capacity of urban modern roundabouts subject to outer diameter

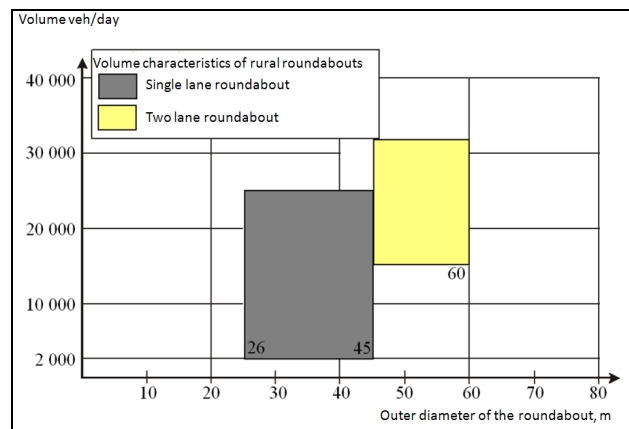


Fig 7. The capacity of rural modern roundabouts subject to outer diameter

Comparing one-lane roundabout with signalized intersection, roundabout's capacity will be higher, and the vehicle waiting time will be shorter (Fig 8) (FHWA, 2000).

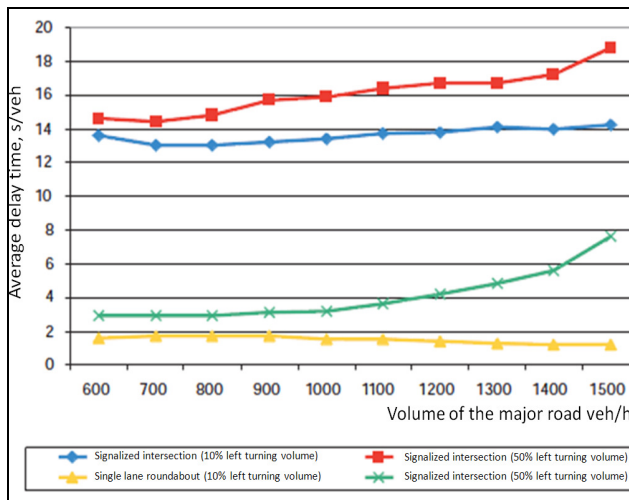


Fig 8. The average delay in at-level junctions subject to traffic volume

Problems in the roundabout may arise only during peak hours – at this time junction's capacity may be slightly higher in a traffic-light controlled intersection. Also roundabout's capacity may be influenced by pedestrian traffic. That is why, where there is high transport intensity, so-called "turbo" roundabouts can be built. They are recognized as the world's most proven inventions of modern road infrastructure (Figure 9).

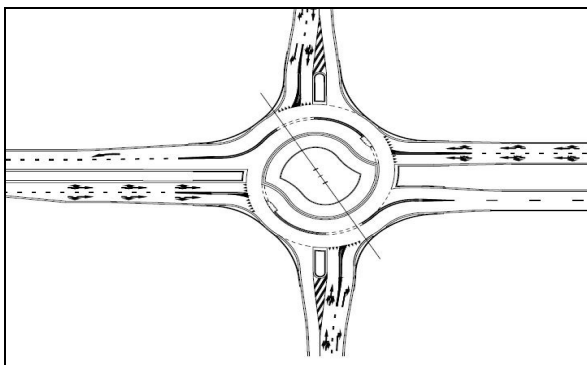


Fig 9. Typical scheme of „turbo“ roundabout

It is important to note that in the roundabout a turn can be made even by a long vehicle. If a heavy vehicle driver loses his way or takes wrong direction, it is quite difficult for him to turn around in simple tripartite or quadripartite intersection, while in the roundabout he can go in circle and take the right direction. That is why in France and other countries' industrial areas with a large number of logistics centers and enterprises, roundabouts are installed for drivers' convenience.

One of the main advantages of roundabouts compared to other types of intersections – intersected roads are not divided into main and minor. All of them are mi-

nor. A vehicle coming from any direction gives the priority to the traffic in circle. In the usual tripartite or quadripartite intersections the accident is caused by the driver who at a low speed enters the intersection from a minor road. The consequences of an accident are caused by a driver going on main road at high speed. Meanwhile, the principle of merging only minor roads of roundabout protects people health and lives.

5. Pedestrian traffic in modern roundabout

Modern roundabouts are very "friendly" for pedestrians. Since in this type of intersection the speed of vehicles is low, it is very easy to install crossings or passages (depending where a roundabout is built: if in residential area – crossings, in suburbs - pedestrian passages are installed) where pedestrians will be very safe. In the approaches of roundabouts safety islands may be installed for pedestrians – in this way they can safely cross one lane, wait in safety island if needed, then cross another lane. Near such roundabouts it is convenient to build bus stops and pedestrian pathways. The idea is that in these intersections pedestrians do not have to step into traffic lanes and they can feel safe (Fig 10). Pathways and passages installed around roundabouts can be adapted for cyclists too, which ensures the safety of all road users.

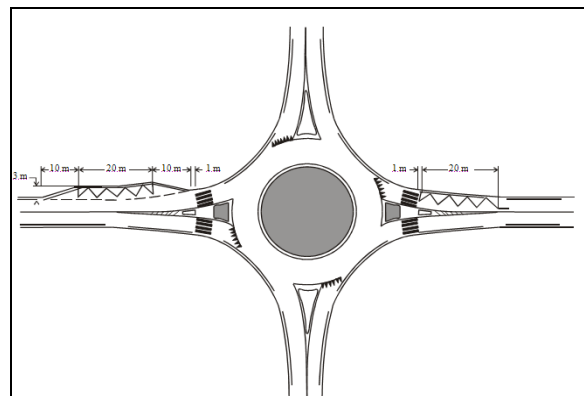


Fig 10. The adaptation scheme of modern roundabouts to public transport and pedestrian's traffic

6. Advanced engineering tools for modern roundabout

In order to make the roundabout orderly, informative, safe and convenient, proper road mark signs (especially if there is more than one lane), pavement markings and informative panels must be installed. The purpose is that the driver could choose the needed lane before entering the intersection. Vehicle movement must be arranged properly so that the driver should not change lanes within the intersection or just before entering it. The driver must be informed about the lane choice of his further direction at least 200 meters before entering the intersection. It is convenient to install road lighting in roundabout central island. Then all the road parts of the roundabout are illuminated.

The modern roundabout, installed in a small town or suburb changes aesthetic view of the location. In other

countries, these kinds of intersections are decorated with flowers and trees. Not only road builders, but also town residents contribute to the maintenance of roundabouts.

As we can see, the roundabouts are not only aesthetically attractive, but also allow reaching desired destination in safe and convenient way. They are convenient in the terms of traffic organization – driver does not have to overcome difficult left turns, he can choose the right direction traveling safely within roundabout.

7. Analysis of capacity, delay, emissions and fuel consumption in traffic light controlled intersection and modern roundabout

To conduct a survey of emission levels, maintenance standards, traffic capacity, delay time, fuel consumption in roundabouts and traffic light controlled intersections the Australian company Akcelik & Associates Pty. Ltd. computer program SIDRA INTERSECTION was used. A typical quadripartite intersection where roads intersect at an angle of 90 degrees was chosen. Average annual daily traffic - 2000 vehicles. During rush hours - 195 cars. Computer program created three different models of intersections:

- single lane roundabout;
- traffic lights controlled with two phases signal, where one lane and one traffic light phase is designated for driving straight and for left turn;
- traffic lights controlled with four phases signal, where separate lanes and traffic light phases are used for left turn.

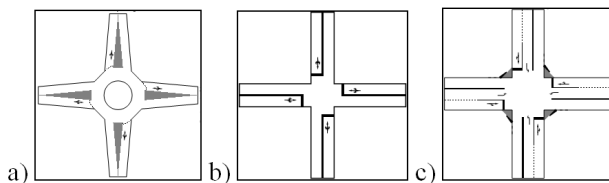


Fig 11. The schemes of modeling at-level junctions. Roundabout (a), with 2 phases traffic lights (b), with 4 phases traffic lights (c)

The required data for analysis is shown in Table 2.

Table 2. The data about modeling junctions

Parameters	Type of intersection		
	Roundabout	Traffic lights controlled	
		2 phases	4 phases
Width of entrance/exit lane, m	4 / 4,5	3,5 / 3,5	3,5 / 3,5
Central island, m	3	-	-
Number of traffic lanes	1	1	2
Central island diameter, m	16	-	-
Width of circle driveway, m	6,5	-	-
Average fuel price, Lt	3,6	3,6	3,6
Traffic intensity during rush hour/ traffic intensity a day, cars/h/cars.h	195/2000		

One of the most important parameters indicating the efficiency of the roundabout intersections is level of service. Level of Service (Level of Service (LOS) is a qualitative measurement unit, that characterizes the state of traffic conditions. The level of service indicator is based on parameters such as speed, travel time, freedom to maneuver, traffic obstruction, driving comfort and convenience, cost, speed, etc. The level of service also depends on the traffic volume, lane width and number and the flow of heavy vehicles. Level of service is depicted by letters A, B, C, D, E and F (FHWA, 2000):

- A - ideal traffic conditions, low intensity, traffic users have no contact with each other;
- B - relatively low volume of traffic, the impacts of traffic users to one another are sufficiently small;
- C - average volume of traffic, traffic users freedom to maneuver is restricted, low comfort level, focus is needed to safely perform a maneuver;
- D - Traffic intensity variable, difficult to maneuver;
- E - Traffic intensity is high and volatile, infrastructure is congested, it is almost impossible to perform the maneuver;
- F - maximum volume of traffic, congested flow resulting inactivity and downtime, there is neither comfort nor convenience to drive.

The study results are presented in Table 3. The results show that having a traffic intensity of 2000 cars the most effective solution is the roundabout. This type of intersection not only ensures a small number of conflict points, and at the same time a low accident rate, but also it becomes possible to reduce emission and ensure a higher level of service. There is nearly half shorter waiting time in roundabouts comparing to traffic lights controlled intersections, also lower fuel usage is needed and the intersection passing time is shorter. Similar results were obtained in Sweden in 2002 where Varhelyi conducted emission tests first in traffic lights controlled intersection which was reconstructed to a modern roundabout. The study showed that after the reconstruction the emission of CO decreased by 29%, NOx - 21%. Analyzed intersection carried 23,500 vehicles/day.

Table 3. The data gained of modeling in roundabout and in junctions with traffic lights

Results	Type of intersection		
	Roundabout	Traffic lights controlled	
		2 phase	4 phase
Effective junction capacity, veh./h	2528	1809	933
Level of service/ Level of service of left turn	A/A	B/C	A/B
Intersection completion degree	0,076	0,148	0,187
Average waiting time, s/veh.	8,5	14,9	18,3
Fuel consumption, L/h	18,5	19,2	20,8
Average intersection zone crossing time, s	51,3	55,9	69,6
Emission, kg/h CO ₂ /CO/NO _x	46,4/ 3,34/ 0,1	48,2/ 3,52/ 0,104	52,2/ 3,64/ 0,108

The results of analysis of accident rates and the data of modeling of the intersections suggest that one of the most effective types of at grade intersections is a modern roundabout, and in the future they should be regarded as one of the main type of at grade intersections in Lithuania. While building new or renovating existing at grade intersections, installing modern roundabout should be taken into first consideration.

8. Conclusions

1. Rapidly changing pace of life influences rapid rise in the level of auto motorization. Along with this accident rates, emission, travel time is increasing. Although in recent years, the adaptation of complex range of measures is taken to decrease accident rates, they still remain high enough in intersection zones.
2. One of the most effective solutions is modern roundabout installation at grade intersections.
3. Analysis of accident data at intersections that have been reconstructed from road signs or traffic lights controlled intersections to modern roundabouts shows that accident rate decreased by 95% in the latter.
4. There are fewer conflict points in roundabouts comparing with other at grade intersections. Quadripartite intersection has 32 conflict points; three leg intersections have 9 conflict points. Meanwhile four leg roundabouts have 8 conflict points, and tripartite roundabout has six conflict points.
5. Modeling a roundabout and two types of traffic lights controlled intersections with the 2000 vehicles per day intensity with computer program Sidra Intersection the results showed that fewer emissions, higher levels of capacity and higher level of service is achieved in roundabout.
6. According to research results the conclusion can be made that modern roundabout is one of the most proven at grade intersection type and it should be considered as the safest at grade intersections in Lithuania.

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