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THE ROAD TRAFFIC SAFETY ON THE ROUNDABOUTS

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У статті розглядаються основні питання виникнення дорожньо-транспортних пригод на вулично-дорожній мережі міст, а також проаналізовані особливості підвищення безпеки дорожнього руху та зниження нещасних випадків на перетинах вулиць і доріг.

В статье рассматриваются основные вопросы возникновения дорожно-транспортных происшествий на улично-дорожной сети городов, а также проанализированы особенности повышения безопасности дорожного движения и уменьшения несчастных случаев на пересечениях улиц и дорог.

The article describes the main issues of the road traffic accidents on the city street and road network, and analyzes the specifics of the road safety improvement and the traffic accidents reduction on intersection of the streets and roads.

Problem statement

Productivity, efficiency and traffic safety are the main criteria for the vehicle performance evaluation. The growth of automobilization and the noncompliance of the city central parts with the modern vehicles requirements create the preconditions for the increase of the road traffic accidents (RTA).

Considering the periods of the automobile transport development since 1887, it should be noted that two deaths were registered as a result of road accidents in Great Britain in 1896, and one accident — in the U.S.A in 1899 [1]. But by the end of the first decade of the last century there had been serious problems, and in the middle of the century street injuries took third place in the number of deaths among the most dangerous diseases, after malignancies and cardiovascular diseases.

Analysis of the latest researches and publications

The following authors described the improvement of the road traffic safety: D.U. Chumacov [1], M.S. Fishelson [2], E.M. Lobanov [3], A.Yu. Mykhailov [4], V.F. Babkov [5], A.V. Tolok [6].

The goal of the research

To identify the role of the single-level road intersections in traffic management and reduce the accident rate on the streets and roads of the settlements.

A roundabout as a method of the accident rate reduction and the road safety improvement on the street and road network

Number of accidents in automobile transport is the highest in comparison to other modes of transport. The average ratio of the death toll per 100 million passenger-km for different modes of transport is: 0.35 — for railway transport, 0.53 — for air transport, 2.18 — for automobile transport - [5].

During 2000–2011 the number of accidents on the roads of Ukraine increased by nearly forty-four percent. In addition, the severity of consequences in the FSU countries is by 10-12 times higher than in other developed countries [1].

Over recent years the problem of street injury prevention has become the focus of city planners, transport workers, road builders, sociologists, doctors and psychologists. The

specialists from many countries of the world try to find the solution to this problem [2].

The causes of dangerous situations on the road network

The causes of RTA during street traffic are divided into two groups:

- subjective, which are linked with the incorrect behavior of the person (driver, pedestrian, passenger);
- objective, which are determined by the irregularity or the defect of technical means (vehicles, components of streets and roads, means of traffic management, etc.).

Considering the causes of RTA as the result of the state of highways and streets, the following most dangerous elements can be specified [4]:

- areas that pass through the settlements and differ with the large traffic volume of traffic and pedestrians, and have various motionless obstacles, such as cars that not only narrow the roadway, but also limit the visibility of the road.

According to statistics 20-30% of all accidents occur on the roads and streets passing through settlements;

- single-level road and street intersections, at which 10-30% of all accidents occur;
- areas with a low quality road surface.

During the year the number of road traffic accidents at such areas can range from 30 to 70% of all road traffic accidents;

- areas with prolonged and steep ups and downs, in which the number of traffic accidents is 7-25%;
- curves in the plan with a short-range;
- areas with a limited visibility in plan and longitudinal sections;
- bridges and overpasses with insufficient carriageway. In these areas there are about 3% of accidents, which occur most often in the dark hours of the day.

The current state of roads and streets in Ukraine

In 2011 186.2 thousand accidents were registered on the motor roads in Ukraine, 4.3 thousand of which were fatal. It should be noted that 74.2% of traffic accidents occurred in the

settlements, as the result of them 2.2 thousand people were killed and 25.6 thousand people were injured. Static data are shown in table 1.

Table 1

Road traffic accidents on the roads and streets of Ukraine by years

Characteristics	2006	2007	2008	2009	2010	2011
RTA, thous.	195.6	278.8	312.8	229.9	204.2	186.2
with the injured people	49.5	63.6	51.3	37.0	31.9	30.9
with fatal consequence	6.6	8.4	6.8	4.7	4.2	4.3
People injured in road traffic accidents, thous.	67.6	88.1	71.0	51.0	43.9	42.7
Dead	7.6	9.6	7.7	5.3	4.9	4.8
Wounded	60.0	78.5	63.3	45.7	39.0	37.9
RTA in the settlements, thous.	168.3	195.6	230.5	169.8	148.7	138.0
Died, thous.	3.8	4.8	3.6	2.3	2.2	2.1
Wounded, thous	43.3	56.6	44.0	31.7	26.7	25.6

According to the State Traffic Patrol Department report, published in January 2012, in 2011 as a result of RTA 4831 persons died in Ukraine that is allegedly in 0.9% less than the last year, when 4875 persons were killed. As is well-known, traditionally Ukraine ranks the first place in Europe in mortality and injury on the roads. The dynamics of road traffic accidents on the street and road network of settlements in Ukraine by years can be traced in Figure 1.

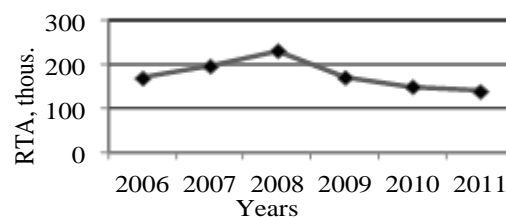


Figure 1. Road traffic accidents on the streets of Ukraine

In 2010, according to the UN, Ukraine ranked second among 49 countries in Europe for mortality due to RTA, just after the Russian Federation.

The mortality rate per 1 million population in Ukraine is 103, while, for example, in Italy - 68, Germany - 45, UK - 31. It should be noted that the number of cars in Ukraine is much lower than in Europe: 184 vehicles per 1000 population, compared with, for example, 510 vehicles in Germany [1].

Analyzing the dynamics of road traffic accidents in Ukraine over the past five years, it should be pointed out that the annual decline observed since 2007, ranging from 8-20%, should rejoice. But comparing the rates of mortality and the loss of property as the result of the road traffic accidents with the same rates in the developed countries, it should be noted that our situation does not develop in the best possible way. At the same time, in the EU countries together with the increasing quantity of automobilization (1-2% per a year) the number of RTA hardly grows, and the number of deaths in RTA has steadily (1-2% per a year) decreased [1].

Very high rate is in Ukraine - 70-75% of the total annual number — RTA that occurred in settlements, exactly where a large population resides and most of the vehicles are concentrated.

It should be specified that the number of accidents that occur on the street and road network settlements in Ukraine, is characterized by the fact that the main street has approximately 87% of all RTA [4].

The RTA distribution by the elements of the main is (% of all RTA on the main street and road network) [6]:

- on the intersections of main streets - 28%;
- including the intersections of main streets:
- of city value - 24%;
 - of city-district value - 30%;
 - of district value - 46%;
- on the main street section - 72%;
- including a section of streets:
- of city value - 43%;
 - of district value - 57%.

Analyzing the accident rate on main streets of the settlements in Ukraine it should be noted that the intersections, especially of the main streets of the district value are the most accidental. At the intersections of the main streets: the collision of vehicles - 64%; auto-pedestrian accidents - 22%, head-on crash - 4%, auto-cyclist accident - 4%, other RTA - 6% [6].

It should also be specified that it's mainly single-level intersections of the controlled traffic. At intersections of streets and roads it is necessary to permit traffic flow in directions that intersect each other, and this leads to conflict points (characterized crossing, merging and separation of traffic).

Methods of improving road safety at the intersections

To develop a set of measures to improve road safety at the intersections it is necessary to know the degree of their security. The degree of road safety at the intersections depends on the direction and intensity of traffic flows which overlap, the number of points of intersections, merging and separating flows, and the distance between them.

In addition, research shows that the intersections of highways significantly reduce the capacity, creating significant delay of traffic flows, as a result of which they become places of high concentration of automobile emissions, noise and other adverse effects on the environment [1, 2, 3].

According to the analysis of various literature [1, 6], the stabilization of the overall statistics of accident rate, reducing the RTA severity abroad and the increase of the intersections capacity is possible through the active implementation of roundabouts on the roads and streets of settlements.

Many researches on the impact of roundabouts on the RTA number have been conducted in the European countries. Among them — *Lalani*, 1975 (UK); *Green*, 1977 (UK); *Lahrman*, 1981 (Denmark); *Cedersund*, 1983A, 1983B (Sweden); *Senneset*, 1983 (Norway); *Brude og Larsson*, 1985 (Sweden); *Johannessen*, 1985 (Norway); *Hall og McDonald*, 1988 (UK); *Nygaard*, 1988 (Norway); *Giaever*, 1990

(Norway); *Tudge*, 1990 (Australia); *Van Minnen*, 1990 (Netherlands); *Jorgensen*, 1991B (Denmark); *Brude og Larsson*, 1992 (Sweden); *Dagersten*, 1992 (Switzerland); *Holzwarth*, 1992 (Germany); *Hyden, Odelid og Varhelyi*, 1992 (Sweden); *Jorgensen og Jorgensen*, 1992 (Denmark); *Kristiansen*, 1992 (Norway); *Schnull, Haller og Von Lubke*, 1992 (Germany); *Brilon, Stuwe og Drews*, 1993 (Germany); *Schoon og Van Minnen*, 1993 (Netherlands); *Jorgensen og Jorgensen*, 1994 (Denmark); *Seim*, 1994 (Norway); *Voss*, 1994 (Germany); *Дорожній департамент м. Осло*, 1994 (Oslo Veivesen, Norway); *Flannery og Datta*, 1996 (USA).

For example, in Australia it is registered that the accident rate is reduced by 74%, while the material costs of RTA decreased by 32%, and the number of RTA involving pedestrians decreased by 68%. On 230 intersections of New Wales their conversion into roundabouts has the following results - see table 2.

Table 2

The effectiveness of roundabouts implementation in the State of New Wales

Index	Number		Reduction
	Before roundabout arrangement	After roundabout arrangement	
The average number of RTA on one intersection per a year	3.910	2.289	41 %
Average number of RTA with injured people on one intersection per a year	1.045	0.571	45 %
Average number of RTA with dead people on one intersection per a year	0.024	0.009	63%

In Belgium after the conversion of conventional intersections into the roundabout, the average number of RTA with injured people on the one intersection per a year decreased by 42% from 1.352 to 0.789, with an average number of special severity RTA of one intersection per a year - from 0.373 to 0.194.

But the subject of discussions was a high risk of the intersections for cyclists (table 3).

Table 3

Relative levels of accident rate on the intersections of UK

The participants of traffic	Relative accident rate, accidents/10 ⁷ of automobiles	
	Regulated intersections	Mini-Roundabout
Cyclists	175	189
Motorbikes	240	237
Automobiles	48	27

In some researches (Lalani, 1975; Van Minnen, 1990; Jorgensen 1991; Schoon og Van Minnen, 1993) the roundabout influence on the number of RTA involving different groups of road users was featured. These results are rather inconsistent and unreliable. It was revealed that the number of RTA after the intersection conversion into the roundabouts varies widely (table 4).

Table 4

Influence of the single-level intersection conversion into the roundabouts on the number of RTA

The consequences of RTA	Percentage change in the number of RTA		
	Influence on the types of RTA	The best result	Limits of variations
Roundabout on T- intersection			
RTA with injuries	All types of accidents on the intersection	-27	(-40; -12)
RTA with loss of property	All types of RTA on the intersection	+52	(+29; +78)
Roundabout on X- intersection			
RTA with injuries	All types of RTA on the intersection	-35	(-46; -23)
RTA with loss of property	All types of RTA on the intersection	+43	(+37; +50)

It should be noted that the organization of the roundabout traffic can reduce the number of RTA with injuries by 25-35%. This applies to both intersections, which were previously governed by the duty to give way, and to intersections that were previously regulated by the traffic lights. The risk of RTA with human losses on the roundabout (number of RTA per 1 million vehicles entering the roundabout) is much less than for any single-level intersection (Giaeber, 1990), but the number of cases with the loss of property increases.

RTA statistics in France shows that the number of RTA per a year on roundabouts is constantly decreasing. According to data of 2002, the average number of RTA per a year on one section was only 0.05.

The roundabouts had significant repercussions in Germany, where the existing single-level intersections have been converted into roundabouts with increasing frequency. At present in Erft-Kreis alone 111 roundabouts of different configurations function, both in cities and beyond. In Baden-Wurttemberg 400 roundabouts are in operation.

According to researchers, the intersections have the following data:

- the number of RTA decreased by 30%;
- the number of deaths decreased by 88%;
- the number of seriously wounded people decreased by 87%;
- the number of slightly wounded people decreased by 60%.

Another advantage of roundabouts is that the regulated intersections often have problems with the traffic lights. In Erft-Kreis every year police registers about 800 such cases.

The researches conducted in Norway show that roundabouts have higher capacity than the regular single-level intersections, which have a sign "Give way", and intersections with traffic light control [5]. Increasing of capacity is explained by maneuvering associated with intersections and turns, which often require waiting for the required interval between cars and create obstacles for other cars, shifted in the roundabout traffic, and, as a result, traffic

participants lose less time in roundabout traffic than in intersections of other types.

Despite the fact that the roundabout traffic reduces the speed, the travel time through the roundabout is less in comparison to other types of intersections. The value of gains over time depends on the traffic intensity on the separate intersection, fluctuations in the intensity within 24 hours and distribution of traffic flows by the adjacent roads. The absence of conflicting points of the traffic flow intersections reduces the number of road traffic accidents.

Advantages of roundabouts

After completing the analysis of the researches on the single level intersections, the following advantages in the organization and road safety can be specified:

- the possibility of transport admission without control at the variable relations of flows according to directions;
- the convenient admission of routes of passenger transport and advantageous conditions of the transport turn in the reverse direction;
- the possibility of rational organization of traffic at intersection on the area of more than four directions;
- the elimination of opposing flows conflicts;
- the impact on the traffic condition;
- the loss of time on the roundabouts is considerably less than on the single-level intersections;
- the traffic pattern is simple and clear for drivers;
- the better conditions of the left turn implementation;
- the roundabout traffic arrangement can reduce the accident rate;
- the provision of continuous traffic;
- the large capacity;
- the maintainance of the traffic flow continuity at driving through intersection;
- the roundabouts with small central islands and the increased number of traffic lanes at the entrance are characterized by a high capacity,

which is compared to the capacity of intersections in different levels;

- ease of entry into the settlement;
- capital costs of the roundabout arrangement in different levels.

Conclusions

Roundabouts occupy the intermediate position between the uncontrolled and controlled intersections by being self-controlled. Their application reduces the number of accidents with injured people to 50% in comparison to intersections of the standard configuration. As the result, the number of conflict points (there are less safe points of confluence and branch) is significantly decreased, the conflict areas are liquidated, where the most severe collision accidents occur; the correctly projected junction with the roundabout practically fully eliminates to 1-3 severe accidents per a year.

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