ханню. Основною перевагою таких респіраторів слід відзначити невелику вагу, а також мінімальний опір диханню. Остання характеристика дозволяє перебувати в захисному засобі протягом кількох годин. Тиск на працівника буде знижено, що виключить дискомфорт.

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Рукопис подано до редакції 03.03.17

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MICROSCOPIC SIMULATION OF ROAD TRAFFIC CONGESTIONS AT T- AND X-INTERSECTIONS

The goal of research. The additional measures for road safety improving on T-shaped intersection with X-shaped one in Kryvyi Rih were introduced in the article. The research object is a road traffic congestion of uncontrolled intersection with main and minor roads. The aim of the study is to determine problem and areas unsafe for vehicle and pedestrian traffic. The part of the road under study consists of T- and X-intersections that may cause the following problems: traffic intensity exceeds the intersection capacity, both drivers and pedestrians violate traffic rules, warning signs are absent or improperly arranged.

Methods. Visual observation and simulation modelling were used in the study.

Scientific value. The developed simulation model of the intersection in microscopic flow simulation software PTV VISSIM taking into account field data of vehicle and pedestrian flows densities indicators is seen scientific value.

Practical utility. Based on the simulation it was determined that an impressive traffic queue take place from Ivan Avramenko St. to Cosmonauts St. with the direction changing to the opposite and left-turning streams from Cosmonauts St. to Ivan Avramenko St. The results of intersection simulation shows a congestion of 11 vehicles on average that increases vehicles' passing time for this part of the road. Also, there is no safe access to the bus stop.

Results. On the basis of the obtained data on the passing time and the congestion length additional measures for increasing safety are suggested that consist in establishing an uncontrolled crosswalk to provide safe access to the bus stop, developing the project to remove the starting bus stop onto the minor road and widening the unsafe part of the road.

Keywords: uncontrolled intersection, simulation modelling, traffic safety, passenger transport, crosswalk, traffic congestion.

Problem Setting. Motorways are a source of hidden dangers. The problem of safety is gaining greater importance along with motorway network increase. In Ukraine the total length of roads makes over 170 000 km and is still growing. Roads are being repaired and improved; new types of surface are appearing, new warning signs are being installed. But all these measures do not always secure traffic safety. Accidents and hazardous situations are often caused by drivers as well as pedestrians. The most common places of danger are uncontrolled intersections where not all necessary sighs are installed and the traffic density is above standard [1, 2]. Without proper warning or priority signs the driver passing the intersections for the first time can cause an accident. So can pedestrians unwilling to get to the crosswalks.

Kryvyi Rih is Ukraine's longest city and one of the largest transportation hubs in Dnipro region with over 2788 km of roads [4].

As it is an industrial city with both public and technological transport, it is rather difficult to maintain the proper state of roads.

Though 156 roads were repaired and 15 intersections were equipped with appropriate signs and traffic lights in 2015, and some of them have been equipped with video cameras in 2016, the problem of safety is still urgent, especially at uncontrolled intersections [5].

Cosmonauts St. – Ivan Avramenko St. intersection is one of them.

As seen in Fig.1, this is an uncontrolled T-intersection changing into X-shaped one with two traffic directions and two traffic lanes. It consists of minor/major roads with the priority sign "Right of Way" and the safety sign "Give the Way", public transport stops and crosswalks [6].

When passing this intersection drivers must strictly observe the traffic rules stated in the Traffic Rules of Ukraine, namely:

"When passing intersections of roads of various significance the driver of a vehicle entering a major road must give the way to other vehicles reaching the intersection on the major road regardless of the direction of their further travel";

"If the direction of the major road changes at the intersection, drivers of the vehicles travelling along it must follow the rules of passing equal significance roads intersection. These rules must also be obeyed by drivers travelling on minor roads";

"In case of impossibility of determining the road surface (darkness, mud, snow etc.) and absence of priority signs, drivers must consider themselves travelling the minor road".

Morning and evening rush hour traffic reaching over 800 vehicles per hour causes congestions that result in vehicles' increased time of passing certain parts of the road.

Absence of a crosswalk to the No.3 bus stop gets pedestrians violate the traffic rules and cross the road in inappropriate places that may be unsafe not only for them but also for drivers as their proper reaction is not always possible.
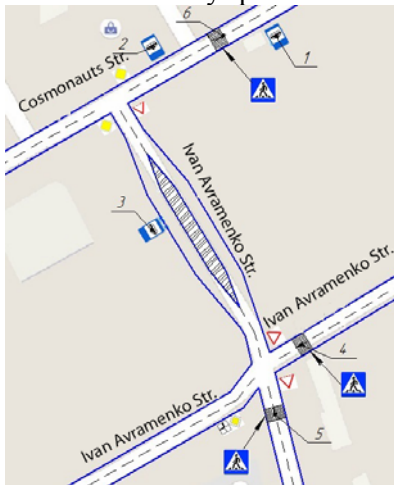

Fig.1. Cosmonauts St. – Ivana Avramenko St. intersection

Analysis of Research and Publications. Literature dealing with traffic safety at uncontrolled intersections [1, 4] does not, however, highlight the problem of passing complex intersections combining two or more T- and X-intersections.

Research Objective and Tasks. In view of the above the following steps must be taken ensure pedestrians' safety on their way to the No.3 bus stop and to decrease the traffic density at this intersection:

to observe traffic density on certain parts of the intersection at different hours of weekdays;

to develop a simulation model of the intersection under consideration on the basis of the obtained data on transport and pedestrian streams;

to determine the time of vehicles' travelling corresponding routes and the length of congestions

to produce recommendations on eliminating congestions and increasing pedestrians' safety on certain parts of the intersection.

Material presentation. The first stage consisted in carrying out a visual analysis of the traffic density in each direction according to types of vehicles (cars, trucks, passenger transport). Fig.2 and Table 1 show congestion places and vehicles' routes where conflicts occur, and length of routes. This data was used to build a simulation model (Fig.3).

The simulation model was built on the basis of the data in PTV Vissim [8]. It helps determine vehicles' passing time on 17 problem routes and the length of congestions at 5 strained points [9, 10].

Fig.2. Routes and congestions

Fig.3. Intersection simulation model

Table 1

Parameters analyzed

Parameter	Length, m
Passing time	
From the city Job Center, Cosmonauts St, to the high-speed tram stop, Ivan Avramenko St.	308,1
From south northwards along Cosmonauts St.	297,4
From the south part of the city along Cosmonauts St. to Vechirniy Boulevard	106,1
From south part of the city along Cosmonauts St.	307,9
From north southwards along Cosmonauts St.	297,5
From the north part of the city along Cosmonauts St. to the high-speed tram stop, Ivan Avramenko St.	308,7
From north eastwards along Cosmonauts St. to Vechirniy Boulevard	307,6
From the north part of the city along Cosmonauts St. to Vechirniy Boulevard	106,1
From Vechirniy Boulevard to the city Job Center along Cosmonauts St.	296,7
From Vechirniy Boulevard Cosmonauts St. towards the "Sun Gallery" shopping and entertainment center	297,2
From the north part of the city, Vechirniy Boulevard, southwards along Ivan Avramenko St,	307,5
From north eastwards along Vechirniy Boulevard	104,2
From the high-speed tram stop, Ivan Avramenko St. side, towards the "Sun Gallery" shopping and entertainment center	297,1
From the high-speed tram stop, Ivan Avramenko St. side, towards the city Job Center	297,1
From Vechirniy Boulevard to the high-speed tram stop along Ivan Avramenko St.	297,4
From Vechirniy Boulevard to the city Job Center along Cosmonauts St.	297,1
From Vechirniy Boulevard towards the "Sun Gallery" shopping and entertainment center along Cosmonauts St.	296,6
Congestion at the intersection	
The No. 217 bus turning in Ivan Avramenko St.	-
From north southwards in Ivan Avramenko St.	-
From south northwards in Cosmonauts St.	-
T-intersection entrance from Ivan Avramenko St.	-
Korniychuk St. From Cosmonauts St. to Ivan Avramenko St.	-

Simulation results of the passing time of the corresponding routes are given in Fig. 4*a*, 4*b*, 4*c*, 4*d*. The analysis of the diagrams shows that on the whole there are small fluctuations of the passing time during the day. However, considerable density can be seen on routes *6*, *7*, *8*, *13*, *17* that pass the part of the road joining T- and X-intersections. To pass it, 1 to 1.5 minutes is required that is too much for such a short distance.
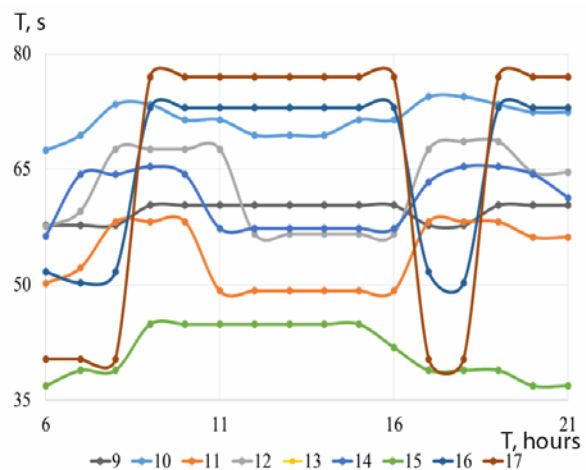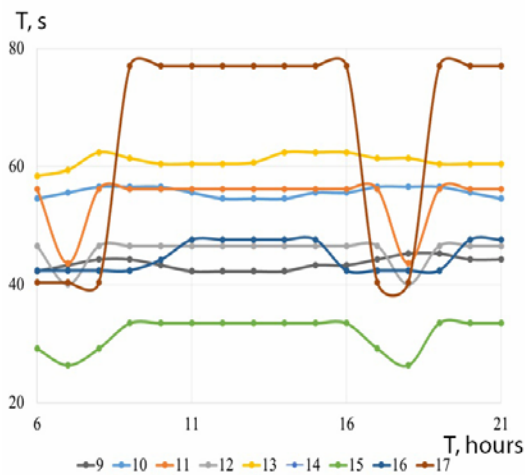
a b
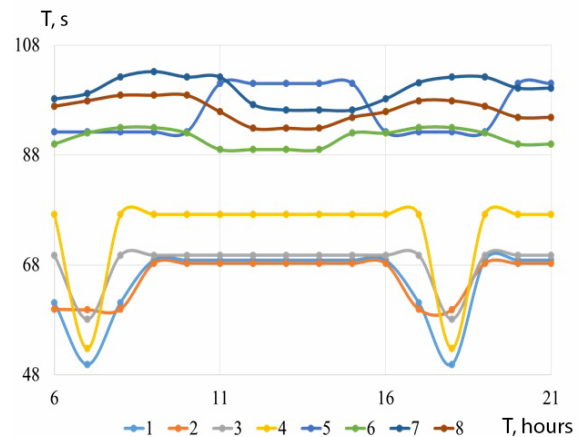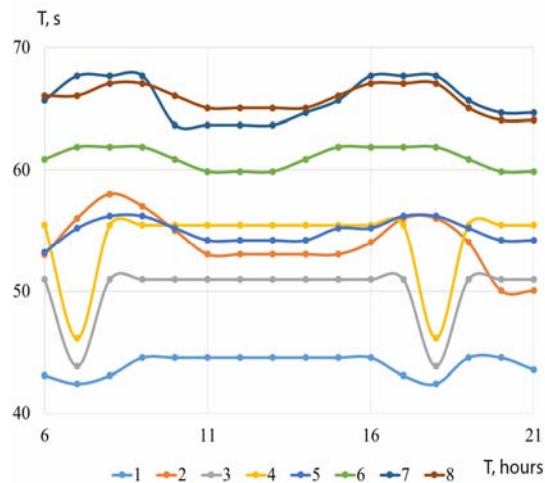
c) d)

Fig.4. Passing time: *a*, *b* – medium; *c*, *d* – maximum

Congestion simulation results are given in Fig. 5*a*, 5*b*. The problem parts here are U-turn of the No. 217 buses ("Cheburashka" shop - Brick factory) that go from Ivan Avramenko St. to Cosmonauts St. with the direction changing to the opposite and left-turning streams from Cosmonauts St. to Ivan Avramenko St. A congestion of 11 vehicles can be observed from 7 to 10 am and from 4 to 7 pm.

The obtained values of passing time and congestion length allow this part of the intersection to be recognized as an unsafe one.

The next stage of the investigation was to simulate pedestrian streams as regards the current location of crosswalks.

The results of the simulation show that in case pedestrians use the crosswalks no danger occurs to their life and health. In practice, it is not quite so.

As there is no crosswalk to the No.217 bus stop on the problem part of the intersection, people try to cut the distance to the stop.

Conclusions. Thus, the situation on the intersection under study is unsatisfactory in terms of pedestrians' safety and transport congestions.
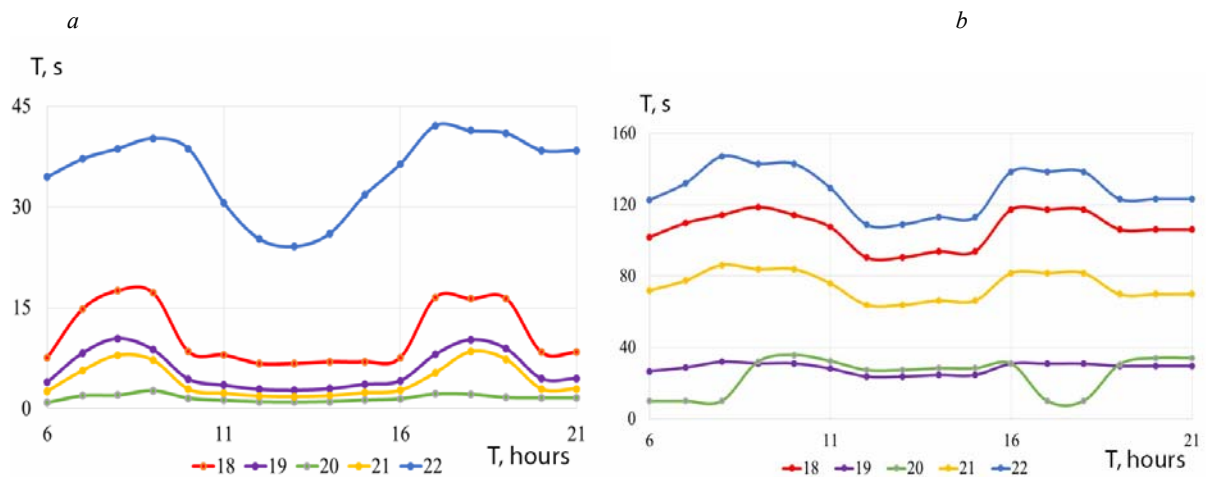
Fig. 5. Congestion lengths: *a*- medium, *b* - maximum

Further Research Outlook. In view of the above additional measures for increasing safety on the uncontrolled intersection must be considered. Among them can be the following:

1. Establishing an uncontrolled crosswalk in Ivan Avramenko St. from the side of Cosmonauts St. to provide safe access to the bus stop.

2. Developing the project to remove the starting stop, parking and turning places for the No.217 buses onto the minor road of Ivan Avramenko St. behind crosswalk No.4. This will help eliminate congestions.

3. Widening part of the road in Ivan Avramenko St. that joins T- and X-intersections.

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