

Study of traffic safety on the street and road network of Ternopil

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Abstract. The road safety issues in the city of Ternopil are studied in this article. The found actual deficiencies were structured according to the main indicators. Based on the analysis of the movement of traffic flows in the morning period, the most problematic sections of the SRN (street and road network) were identified. In general, the speed of traffic flows along the SRN in the evening peak period was found significantly lower than in the morning peak period. To analyze road traffic safety in the city of Ternopil, a cartographic method was applied. Based on the obtained results, the road accidents in Ternopil mostly occur along main streets without clearly defined places of concentration. In this regard, a conditional indicator of the danger of transport corridors of Ternopil was derived, which allows analyzing the predominant location (clustering) of road accidents with victims in each district of the city. The current policy and practices of Ternopil in the field of road safety management need improvement. However, the volume of performed measures does not fully cover the need in traffic safety insurance and information provision of traffic participants. In general, it can be stated that proactive actions in the field of ensuring traffic safety are just starting in Ternopil ("starting city"). Thus, it differs favorably from the vast majority of other regional centers, in which the problem of traffic safety has not been even discussed so far. In addition, the plan for sustainable urban mobility is under consideration in the Ternopil City Territorial Community.

1 Introduction

A modern city is the center of modern life, where there is a concentration of various opportunities for study, work, leisure, etc. At the same time, urbanization leads to a number of problems, such as increasing the time it takes to move from one point of the city to another, increasing the anthropogenic load on the environment, increasing the risks for all road users, etc. As we can see, the development of modern cities requires the creation of an effective system of urban mobility, which is oriented towards its further development.

In the EU countries, the first stage of regulating issues related to the development of urban mobility due to the increase in the number of road users began as early as the 80s of the last century. Therefore, since 1982, the development and approval of urban transport plans for populated areas have become mandatory points with a population of more than one hundred thousand inhabitants, in particular in France. Similar requirements appeared in the legislation of Great Britain. And, in 2009, in the "Action Plan in the Field of Urban Mobility", the European Union adopted the Sustainable Urban Mobility

Plan as one of the most relevant planning concepts in response to problems related to the development of the transport network and the arrangement of urban areas [1].

The creation of plans for sustainable urban mobility should be based on a clear and versatile system of indicators that allow operational monitoring of existing trends in the development of urban areas; they are the basis for making management decisions and a tool for disseminating information and experience between city communities. Indicators of sustainable development should include key areas of the life of the city community and reflect institutional aspects of information disclosure, ensure the presence of free competition and effective control over the activities of the city government by the community.

Based on the world experience, an important direction of sustainable development of urban mobility is ensuring road traffic safety for all its participants. The development and implementation of organizational measures and technical solutions that allow reducing accidents on the roads is a prerequisite for creating a safe environment for the movement of all categories of the population.

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2 Main part

Based on a detailed analysis of reported statistical data on the number of traffic accidents by type, location, reasons for their occurrence, etc., a number of significant shortcomings were revealed. This approach makes it possible to comprehensively assess the existing problems of the city and determine effective methods of solving them in order to reduce the number of accidents and the number of victims.

The analysis of the current state of traffic safety is based on data on registered traffic accidents in 2018-2020 from the Unified Information System of the Ministry of Internal Affairs of Ukraine and the information search system

ARMOR, provided by the traffic safety department of the patrol police department in the Ternopil region.

According to the above, to develop a sustainable urban mobility plan for the Ternopil City Territorial Community (CTC), the state of road safety in the city should be studied.

Transport services for the transportation of passengers are provided by rolling stock of electric transport of the Communal Enterprise "Ternopilelectrotrans", as well as by private entrepreneurs, according to the received permits.

For the statistical analysis of traffic accidents and injuries in European practice and in Ukraine, key indicators are used, which have the greatest importance from the point of view of traffic safety management, presented in Table 1.

Table 1. Key indicators, which have the greatest importance from the point of view of traffic safety management

Indicator	2018	2019	2020
Total number of road accidents in the city of Ternopil	1133	1179	1276
Total number of victims	2326	2379	2546
including - without damage	2139	2122	2301
easily injured	149	218	185
died at the scene of the accident	4	12	2
died on the way to the hospital	1	1	2
died in the hospital within 30 days	4	4	4
seriously injured	29	22	52

The data in Table 1 testify to the general tendency towards worsening of the situation with traffic injuries.

The idea that our life is priceless leads to the leveling of questions related to determining the monetary assessment of its value. According to ethical standards, a person's life does not fall under the understanding of the product, therefore calculating its value is immoral. However, at the state level, this statement becomes a good justification for the extremely low amounts of compensation payments. In addition, this, in turn, leads to the fact that at the state level it is considered superfluous to invest in improving the level of safety, be it road traffic or any other, since it does not bear significant costs in the event of an emergency.

In connection with the above, an assessment of the value of human life is necessary for conducting an adequate state policy in the field of not only compensatory damages, but also for the development and implementation of measures that will ensure increased

safety and minimization of risks in all spheres of society's life.

In countries with a high level of development of road safety management, in particular, in the countries of the European Union, economic losses due to road injuries and deaths are estimated in monetary terms. For this, officially recognized scientific estimates of the statistical value of life (Statistical Value of Life) are used. These indicators, in particular, are used to evaluate the economic efficiency of measures in the field of road safety (Cost-Benefit Analysis). In Ukraine, such assessment tools are currently not used, and there is no officially recognized value of living indicator.

To estimate economic costs in Ukraine, it is recommended to use a simplified methodology, according to which 1 fatal case can be conditionally "estimated" by a weighting factor of 70 indicators of gross domestic product per capita, and 1 case of injury - as 17 indicators of gross domestic product per capita (Table 2).

Table 2. Economic losses due to road accidents that occurred on the territory of Ternopil in 2020

Category	Case	GDP per capita, UAH	The coefficient recommended by the World Bank	Estimated amount of economic losses, UAH
Dead	8	100432.5	70	56242200.0
Injured	237	100432.5	17	404642542.5
TOTAL				460884742.5

Economic losses due to road accidents that occurred on the territory of Ternopil in 2020 can be estimated at approximately UAH 460.9 million or for UAH 2,031.22 per resident of Ternopil CTC.

Based on the analysis of road accidents for the period 2018-2020 (Table 3), 40.2% of all those killed or injured

in road accidents in the city of Ternopil, were vulnerable road users who did not directly use a car, but moved on foot or by bicycle.

The share of pedestrians among all persons killed in traffic accidents is 58.8%, and their share among the injured is 35.7%.

The share of cyclists among those injured in road accidents is only 3.5%, however, the rather low rate of injuries is due to the small number of users of bicycle transport, which, in turn, is due to the low level of safety

and infrastructural support to encourage the use of bicycles.

Motorists, including drivers, passengers of cars, public transport and motorcyclists, account for 41.2% of all fatalities and 60.8% of all injured in road accidents.

Table 3. Analysis of traffic accidents for the period 2018-2020

Category of road users	2018				2019				2020				Total, share		
	Dead		Injured		Dead		Injured		Dead		Injured		Dead	Injured	Participants in road accidents
	Person	%	Person	%	Person	%	Person	%	Person	%	Person	%			
Users of motorized transport	3	1.6	113	60.4	9	3.5	152	59.1	2	0.8	133	54.4	41.2	60.8	59.8
Pedestrians	6	3.2	60	32.1	8	3.1	81	31.6	6	2.4	93	37.9	58.8	35.7	36.9
Cyclists	-	-	5	2.7	-	-	7	2.7	-	-	11	4.5	0.0	3.5	3.3

Based on data from the traffic safety department of the patrol police department in the Ternopil region on the number and causes of road accidents for the period 2018-2020, the largest number of road accidents in the studied

territory occurred due to (Table 4):
 Violation of maneuvering rules;
 Failure to maintain distance;
 Violation of the traffic rules of the intersection.

Table 4. Official causes of road accidents for 2018-2020

Cause	The number of road accidents for the period 2018-2020.	% of the total number of road accidents for the period 2018-2020
Violation of maneuvering rules	1569	43.73
Failure to maintain distance	716	19.96
Violation of the traffic rules of the intersection	409	11.40
Exceeding safe speed	293	8.17
Driving a vehicle while intoxicated	217	6.05
Violation of road and street maintenance rules	73	2.03
Violation of the rules for providing unhindered traffic	58	1.62
Transition in an unspecified place	47	1.31
Violation of pedestrian crossing rules	43	1.20
Failure to meet the requirements of regulation signals	39	1.09
Violation of the rules for stopping and parking the vehicle	38	1.06
Violation of overtaking rules	23	0.64
Unexpected entrance to the carriageway	21	0.59
Driving a defective vehicle	18	0.50
Exit to the lane of oncoming traffic	16	0.45
Failure of pedestrians to comply with the requirements of regulation signals	8	0.22

This indicates the presence of traffic organization problems at intersections, which lead to multivariate travel trajectories and increase the number of road accidents involving several vehicles during maneuvering.

In order to analyze road traffic safety in the city of Ternopil, a cartographic method was applied, which involves superimposing data arrays on the map regarding traffic accident statistics for 2018-2020 (Fig. 1). This approach makes it possible to determine the places of concentration of road accidents. However, during the analysis, it was found that road accidents in Ternopil mostly occur along the main streets without clearly

defined places of concentration. In this regard, a conditional indicator of the danger of transport corridors of Ternopil was derived, which is determined by the ratio of the number of road accidents with victims to the total length of the street (Table 5). Thus, the predominant location (clustering) of road accidents with victims in each district of the city could be analyzed. What's more: locations with a ratio of the number of traffic accidents with victims to the total length of the street are shown in green - up to 3 accidents/km; yellow - 3 ... 5 accidents/km; red - more than 5.

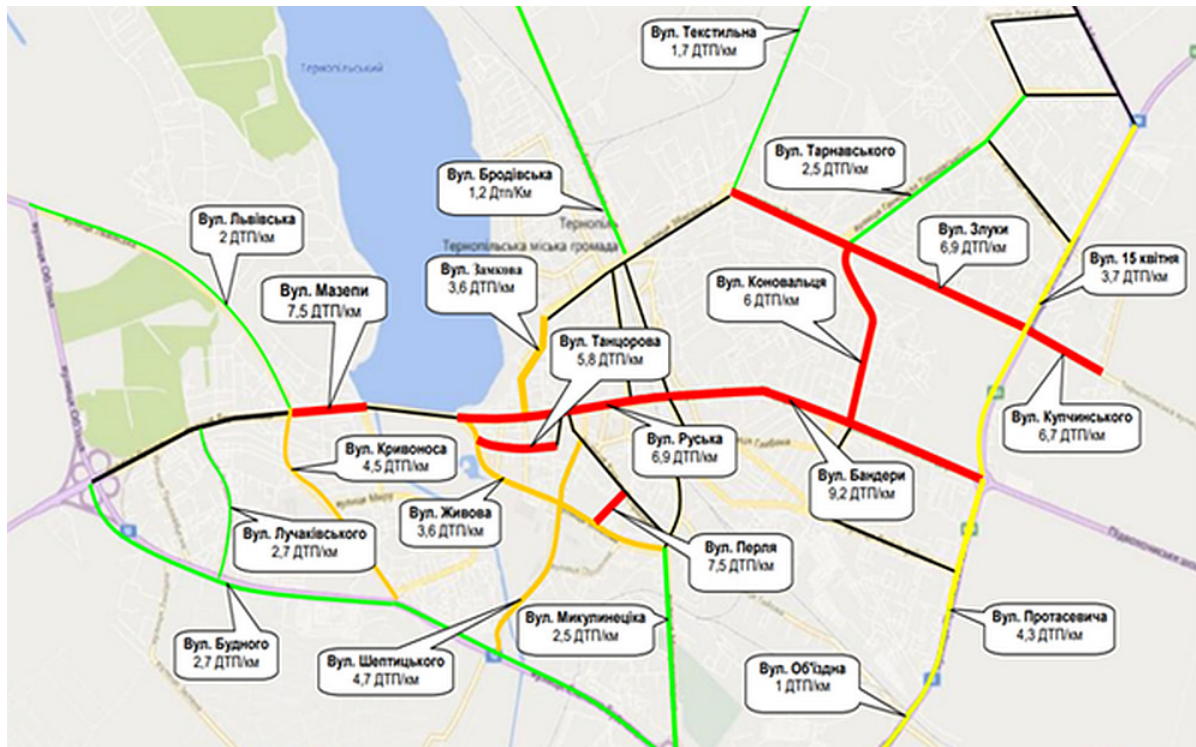


Fig. 1. Locations of concentration of traffic accidents

Table 5. The ratio of the number of traffic accidents with victims to the total length of the street

Street / avenue	Road accident with victims for 2 years	The length of the plot, km	Road accident with victims per 1 km
15 Kvitnia	14	3.8	3.7
Anatiliy Zhyvov	9	25	3.6
Bohdan Khmelnytskyi	2	1.3	1.5
Brodivs'ka	6	5.1	1.2
General Myron Tarnavskyi	6	2.4	2.5
Hetman Mazepa	6	0.8	7.5
Yevhen Konovalets'	9	1.5	6
Zluky	25	3.6	6.9
Zamkova	4	1.1	3.6
Luchakivs'kyi	4	1.5	2.7
Lvivska	3	1.5	2
Maksym Kryvonos	5	1.1	4.5
Mykulynets'ka	16	6.4	2.5
Mytropolyt Sheptyts'kyi	11	2.3	4.7
Roman Kupchyns'kyi	6	0.9	6.7
Rus'ka	16	2.3	6.9
Obyizna	3	3.1	1
Perl'	3	0.4	7.5
Protasevych	10	2.3	4.3
Stepan Bandera	35	3.8	9.2
Stepan Budnyi	20	7.3	2.7
Tantsorov	7	1.2	5.8
Tekstyl'na	8	4.7	1.7

The next stage of the road safety study was the study of 15 intersections on the SRN of Ternopil (Fig. 2). In the study, a number of inefficient design solutions, as well as insufficiently rational organization of traffic, which cause an increase in the risk of road accidents, were revealed.

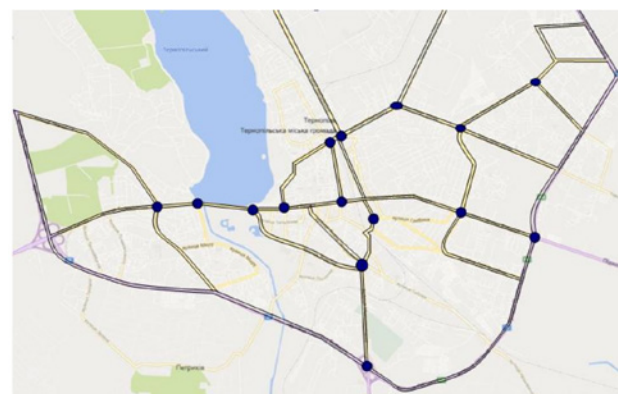


Fig. 2. Intersections of SRN in Ternopil city under study

In study, the infrastructural deficiencies related to road safety in Ternopil were noted:

Kyivska - V. Velikiy st - 8; Zamkova – Ruska st – 8; B. Khmelnytskyi – Ruska st – 2; Berezhanska – Lvivska – Mazepa – Kryvonos st – 15; Bandera – Konovalets' st - 16; 15 Kvitnia - Zluki st - 2; Tatarska – Divocha st – 1; Zamkova – Ruska st - 12.

- There is no marking at certain intersections and in their immediate vicinity, there are no pedestrian crossings at some intersections.
- Cases of non-compliance of the location of the safety islands with the geometric parameters of the transverse profile of the carriageway were revealed, for example, on Tarnavskyi street.

The inconspicuousness of the pedestrian crossing, as well as the people moving through it, is one of the important risk factors that lead to the occurrence of road accidents. This kind of road accident can be divided into two main types:

- hitting a pedestrian;
- passing collisions with a vehicle that stopped suddenly, occurring during the stopping process to give priority to pedestrians.

It should be noted that under the conditions of standard street lighting, pedestrian crossings are hardly noticeable, and drivers of vehicles do not reduce their speed while driving. In order to improve the safety of pedestrians in the city of Ternopil, contrasting point lighting of pedestrian crossings is used, which is one of the positive characteristics of our city. Nevertheless, during the research it was found that it is not present fully at every pedestrian crossing.

Road markings and signs are key infrastructural factors of safety, because these means of traffic organization are informative for drivers, cyclists and pedestrians about traffic rules, the required trajectory and speed of movement, difficult sections and dangerous factors on the road. At the same time, it is necessary not to forget that Road signs have an advantage over road markings and can be permanent, temporary and with variable information. Road signs are the most widespread and effective means of traffic regulation, which provides prompt response to changes in road conditions, the intensity of traffic of vehicles and pedestrians, the composition of traffic flows, etc. [2, 4-11]. One of the main problems of roads in our country is the non-compliance of road signs with the current State Standard 4100:2021 Road safety. Road signs. General technical conditions. Application rules [3].

In the study of Ternopil SRN, the technical inconsistencies in parts of road signs were found:

- There are no double bends around the perimeter of the signs to ensure rigidity, the signs have a curved surface;
- Fastening is done with through holes in the working surface of the sign;
- Fastening elements do not hold the signs securely; there are elements of oxidation;
- The colors of the film have lost their brightness, there are peeling and cracks.

The technical inconsistency of road signs leads to the premature loss of characteristics important for safety, in particular, light-reflective properties, visual and physical integrity of signs, contrast. Therefore, they do not fulfill their function, may be imperceptible to drivers and require additional replacement.

Refusal to use seat belts is one of the biggest risk factors on the roads of Ukraine, although administrative responsibility is provided for both the driver and the passenger, and in the event of an accident, the driver may receive a criminal record. Unlike Ukrainian car owners and their passengers, for Europeans the question of whether or not to use a seat belt does not arise, as this is a generally accepted norm in EU countries. International studies have proven that using a seat belt reduces the risk of injury and death by more than 50%. However, the vast majority of motorists ignore the Traffic Rules, which is

one of the reasons for the increased number of injuries during road accidents. According to statistics, 60.8% of those injured in road accidents in Ternopil are drivers and passengers of cars. Therefore, conducting information campaigns and increasing the level of control over the use of seat belts will contribute to reducing the severity of the consequences, the number of injured and dead.

Another factor causing increased risk on city roads is non-observance of the speed limit. Speeding is the most common cause of road accidents with injuries and deaths. In our country, this indicator is one of the highest in Europe. The high speed of vehicles on the streets of cities and villages is a negative phenomenon that directly affects traffic safety.

First, it leads to an increase in the probability of an accident, because drivers have less time to notice changes in the road situation and react to them, besides, the braking distance of the car increases along with the increase in speed.

Secondly, under such driving conditions, the severity of the consequences increases - the severity of injuries and the likelihood of fatal consequences increase. According to WHO, in an accident that occurred at a speed of 80 km/h, the chances of survival of a pedestrian or cyclist are less than 5%.

In order to bring the Road Traffic Rules of Ukraine in line with European standards and ensure the safety of all road users, a speed limit of 50 km/h was established in populated areas. The problem of excessive speed in Ternopil, as in many other cities of Ukraine, is related to the presence of long straight sections of streets on which there is no need to change the trajectory of traffic; to the absence of traffic lights and other objects of artificial speed reduction, roundabouts; to the presence of excessively wide traffic lanes (more than 3 m).

However, it should be noted that one of the reasons for non-compliance with the speed limit is that for such a serious violation, the driver bears a minor administrative penalty, and in the case of a violation of up to 20 km/h, no fine is provided at all. In other words, with the established limit of 50 km/h, drivers can move up to 70 km/h and they will not get anything for it. In case of speeding up to 50 km/h, a fine of 340hryv is imposed on the driver, but if he pays it for up to 10 days, he actually pays 170 UAH.

Another common problem in the city of Ternopil, as in most cities, is the lack of parking spaces, as well as shortcomings in the organization of the existing ones. In this regard, car owners leave their vehicles in places prohibited by the Traffic Rules, such as in the immediate vicinity of intersections and pedestrian crossings, in the far right lane, in the area of "No Parking" signs or relevant road markings. Such violations reduce visibility, increase the likelihood of collisions with pedestrians, and reduce the capacity of sections of the street network and intersections. Improperly placed vehicles in parking spaces, as well as their return to lanes from "pockets" in violation of the traffic rules, create conflict situations, which also cause inconvenience to other road users and make driving difficult due to disordered parking spaces and lack of space for maneuvering.

3 Conclusions

Based on the above study, it can be concluded that the current policy and practices of Ternopil in the field of road safety management need improvement. In the city, repair works are regularly carried out to maintain the roadway and technical equipment in proper condition, but the quality and volume of the performed works do not fully cover the need to ensure traffic safety, as well as information provision of traffic participants. Research into the causes of road accidents has shown that there are problems with the organization of traffic at intersections in Ternopil, which lead to multivariate travel trajectories and increase the number of road accidents involving several vehicles during maneuvering. The analysis of 15 intersections on the SRN in Ternopil revealed a number of inefficient design solutions, as well as insufficiently rational organization of traffic, which increase the risk of road accidents. There are also questions about the quality of lighting of pedestrian crossings, road markings and signs. In general, it can be stated that Ternopil is a city that is just beginning proactive actions in the field of ensuring traffic safety ("starting city"). Thus, it favorably differs from the vast majority of other regional centers, in which the problem of traffic safety has not been even discussed so far, and this issue in the Plan of Sustainable Urban Mobility of the Ternopil City Territorial Community is under consideration.

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