

The research of the transport infrastructure development in Ternopil

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Abstract. The article is devoted to the problem of studying the state of transport infrastructure of the city of Ternopil in order to further develop a plan for sustainable urban mobility for territorial community of Ternopil city. To satisfy the existing needs of passengers in high-quality transport service, it is necessary to ensure a sufficient number of buses with large and medium passenger capacities. However, according to the principles of sustainable urban mobility, exploitation of the new "green" electric vehicles should be the priority for the modern transport policy of the community. Currently, the most problematic situation with insufficient parking spaces can be observed in the central part of Ternopil. In particular, the city is experiencing such situation due to the growing level of motorization of residents of Ternopil territorial community and, accordingly, the growing demand for the use of individual transport. To solve the current problem, various sources of financing, such as the city budget, the state budget, investments, loans, funds of individuals and legal entities are attracted. Despite this, the implementation of measures still largely depends on the local budget. Analysis of the allocation and development of fundings showed that there has been a prolonged underfinancing of works related to the transport infrastructure of Ternopil. An analysis of the actual indicators of the development of financial resources that have been allocated from the local budget to improve the state of SN for 2020 showed that they did not reach the planned values by 36.4%. Also, in 2020, according to the local budget, it was planned to finance the Program for the development of bicycle infrastructure of the city. The amount of financing was meant to be 2000.0 thousand UAH. However, in fact, no investments were actually made.

1 Introduction

Crises encourage us to implement changes in order to increase the effectiveness of our activities in all spheres of life. And creating sustainable urban mobility plans is no exception. The strategic plan for the development of the city and its transport industry is what is called "the plan for sustainable urban mobility". This plan and its implementation should meet the needs for mobility of people and business entities. And its goal is to improve the overall standard of living. It also emerges as one of the newest tools for planning further development of the city as a whole. In general, it integrates and coordinates the documentation on urban mobility, provides a strategic reflection of priority areas of development, contains an effective system for monitoring and evaluating its enforcement.

The provision of sustainable urban mobility, as well as its role in sustainable development and the formation of a barrier-free environment, were studied by such scientists as: V. Denysenko, N. Margita, I. Mohyla, I. Prokopchuk, L. Sergienko and others. However, the research data are either general in nature or clearly tied to a specific settlement. That is why the issue of researching the

development of transport infrastructure in Ternopil with the aim of developing a plan for sustainable urban mobility is relevant.

An integral part of the sustainable development of mobility in the local community is the provision of inclusive, convenient and safe transport infrastructure for its population. Each project in the field of transport must meet certain requirements that can guarantee its quality. There is a large number of factors that can act as prerequisites for providing a higher level of transport service and a comfortable life of residents in the local community. In particular, such can be the maintenance and renewal of the network of railways, energy facilities, technical systems for organizing and managing the work of the transport sector, rolling stock of public transport and other infrastructure components.

From the point of view of sustainable planning, an integrated approach should be an important criterion in the development of long-term plans for the improvement of transport infrastructure. Such an approach should be based on the principles of sustainable development, and not limited to ensuring the functioning of the transport system in the conditions of existing natural or artificial obstacles. An example of such a limitation can be the

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Seret River and railways, which determine the planning restrictions for transport links between parts of the city.

It is necessary to note the following basic requirements that should apply to sustainable urban mobility projects:

- inclusiveness – certain conditions, under which people with disabilities will not experience exclusivity and will have the opportunity to lead a full life, should definitely be provided;
- energy independence – the development, first of all, of infrastructure for vehicles driven by muscle power and electric engines;
- traffic safety – the health and life of people should be a priority compared to the high-speed movement of vehicles, Moreover, when making a decision, it is necessary to give preference to the residents of the community and their decisions;
- multimodal systems – combinations of several types of movement/transportation (modalities) can significantly improve the entire transport system and reduce the cost of its exploitation;
- sustainable mobility – provision of infrastructure and services for the transportation of passengers and goods. It provides an increase in the economic and social development of the community. It also is safe, effective, and both technologically and economically possible. Moreover, sustainable mobility minimizes anthropogenic impact on the environment.

In other words, all transport projects must fall under three main criteria:

- economical (to be cost-effective);
- social (to take care of the least protected layers of the population);
- ecological (ensure minimization of environmental impact).

In the process of developing a plan for sustainable urban mobility, the whole procedure of setting priorities regarding modes of transportation must meet all three previously discussed criteria and have the following structure:

1. Walking;
2. Bicycle transport.
3. Public transport.
4. Private transport.

Walking is the most sustainable way of movement. The main reasons for it, considering other methods of movement, are that walking is the most environmentally friendly (does not produce emissions), most accessible, and the most cost-effective one (infrastructure for pedestrians is cheaper than for other types of movement) among the others.

Just as walking, bicycle transport is an environmentally friendly form of movement (does not produce emissions); It is also distinguished by its relatively low cost. And this applies to both the bicycles themselves and their maintenance (thereby ensuring the possibility for its use by a wide range of population); In addition, the exploitation of bicycle transport is more cost-effective than the one of private vehicles, and its respectful infrastructure is also relatively cheap.

Public transport is also considered as a sustainable method of transportation since the emissions produced by

it are much less (when calculated per person using it) than when using private transport; More than that, public transport is a relatively affordable form of transportation. And in many cases, it is generally the only one possible (if a person doesn't own a private vehicle). In the end, it provides simultaneous transportation of a large number of passengers thereby reducing the costs of transportation in terms of one person.

Private transport is the least sustainable way of transportation because it produces the most emissions; the cost of cars is relatively expensive, thereby making private transport inaccessible to the least protected layers of the population. However, private vehicles are sometimes uncontested for urgent or long trips, as well as during the transportation of specific goods. In this regard, it is necessary to ensure such conditions under which the use of a private car would be reduced to the minimum required volumes. Thus, in other cases, people would choose more sustainable ways for movement or transportation.

2 Main part

The existing street-road network (SN) of Ternopil is rather branched. However, it is still formed in accordance with the traditional approach of planning transport networks. The main feature of this approach is the development of technical and organizational solutions to improve traffic management (construction, reconstruction, repair of SN sections and road facilities). And the goal of this is to ensure the effective organization of road transport.

SN of Ternopil consists of 244 urban roads and streets with a total length of 209 km. 89% of these roads have a satisfactory condition of the asphalt concrete pavement of the carriageway. The streets of citywide and district significance are the main pieces of Ternopil street network. They provide a connection between the outer exits of the city and its center, and also connect different areas of the city itself. In the city, about 40% of streets have one lane in the direction. And there is also an organized network of one-way streets, which, due to urban restrictions, makes it impossible to increase the capacity of SN facilities in the city. And such a restriction exists even in the conditions of growing demand for the use of the current transport network.

It is worth noting that another feature of Ternopil is also the presence of 17 artificial structures, which are elements of the main SN. Such structures include:

- 6 automobile bridges with a total length of 140.4 m;
- 9 overpasses with a total length of 1794 m;
- 2 pedestrian bridges with a total length of 242.2 m.

However, high-quality and convenient SN involves not only proper maintenance and repair of road and bridge facilities. Beyond that, it also provides construction and reconstruction of main streets, sidewalks, bridges, and overpasses across railway lines. Certainly, all these operations require significant fundings.

In accordance with all the information provided above, the question of conducting a research of the state of the transport infrastructure of Ternopil arises reasonably. And the purpose of such a research is to

further develop a plan for sustainable urban mobility for the territorial community of Ternopil.

The structure of public transport of Ternopil urban community is represented by a network of trolleybus and bus routes (Table 1).

There are 218 bus and 135 trolleybus stops on the route network of Ternopil. And all of them provide a sufficiently high level of transport accessibility in the 500-meter zone from the dwelling place of 96% of the city's residents. All stopping points of trolleybus routes are equipped with stopping facilities, while 17% still remain unequipped at stops with low passenger exchange.

Table 1. The structure of public transport of Ternopil urban community

Indicator	Trolleybus routes	Bus routes
Number of operating routes	9	32
Route network length, km	187,6	650,3
Route network density, km/km ²	3,7	13,2
Number of units on routes	52	172
Total passenger capacity on routes	6650	8584

On the bus routes served by the communal enterprises, there are 41 comfortable low-floor buses. 20 of them are completely new. However, 76% of the rolling stock on bus routes (131 transport units) are privately owned. This ratio significantly complicates the control of updating and upgrading vehicles, taking into account the needs of people with limited mobility.

Among the 60 trolleybuses of ME "Ternopilelektrotrans," 56 vehicles are more than 15 years old. And the average age of the rolling stock fleet of electric vehicles is 26 years. Accordingly, the trolleybus fleet requires a complete update.

To meet the existing needs of passengers in high-quality transport service, it is necessary to ensure a sufficient number of buses of large and medium passenger capacity. Nevertheless, according to the principles of sustainable urban mobility, environmentally friendly electric transport should remain the priority of the community's transport policy.

The city of Ternopil was marked by the introduction of an automated fare accounting system in Ukraine. In addition, a cashless payment system was introduced by VISA/Mastercard/NFC devices in both public and private transport. For now, more than 195,000 residents of Ternopil received personalized and non-personalized cards. These cards allow people to use an electronic ticket in public transport [1 - 5].

There are 56 authorized points across the city where people can replenish their corresponding cards (Figure 1). Also, the online replenishment of the card is also available [2].

To provide residents with the opportunity to purchase a single one-time ticket outside of transport, there are 113

EasyPay self-service terminals operating since 01.10.2021 (Figure 2).

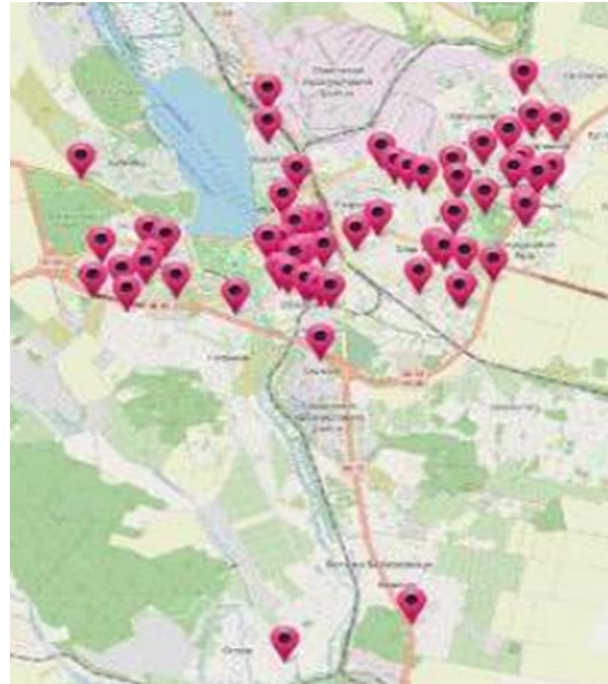


Fig. 1. Locations for sale and replenishment of cards

The absence of the available parking spots is a typical problem for many cities. In Ternopil there are parking lots for different vehicles on 14 different streets [3, 4-9].

In total there are 428 parking spots, of which 399 are for paid parking. Moreover, there are 9 parking machines across the city (Figure 3).



Fig. 2. Locations for purchasing a one-time ticket through EasyPay terminals in Ternopil

The most difficult situation with insufficient parking is observed in the central part of the city. This situation has developed like this in particular because of the concentration of the vast majority of attraction object for transportation in that zone. Other problematic reasons are

also the increase in the level of motorization of residents of the Ternopil community and, accordingly, the growing demand for the use of individual transport. At the same time, most violations of parking rules by drivers have been observed on T. Shevchenko Boulevard, Sheptytsky and Ruska streets, as well as near schools №3 and №4. A similar situation can be observed on the square of the Heroes of the Heavenly Hundred, the intersections of Ostrozhsy str. - Shevchenka blvd., Shevchenka blvd. - Kaminnaya str. - Opilsky str. - Kachaly str. Most apartment buildings in Ternopil were constructed in Soviet times, and back then architects did not care about the formula "one family - one car". However, nowadays, many families possess two, or even more vehicles. Although, it should be noted that the embodiment of this formula in modern realities is a very difficult task. In particular, due to the fact that builders often construct buildings not complying with any standards. In fact, they often build them on the sites of former parking lots.



Fig. 3. Placement of parking lots in Ternopil

In general, the places where you can put a car without breaking the law can be divided into the following groups:

1. Places near residential buildings.
2. Private parking lots.
3. Specially equipped parking places along roadsides.
4. Reserved places outside the roadway territory.

Parking inspectors and municipal police of Ternopil do not always have time to properly control the violation of parking rules. Because of this, most roadsides are often occupied by cars. This, in turn, prevents the free movement of vehicles and pedestrians and increases the risk of unpleasant accidents. In the central part of the city, traffic restrictions are used to prevent parking on sidewalks. More than that, a MAN tow truck, with a carrying capacity of up to 6 tons, usually patrols the areas. It is used to forcibly move cars away. Such forced evacuation of a vehicle may happen if a car is parked in a way that threatens road safety, or in places intended for parking cars of people with disabilities. Due to lack of fundings, the local budget stopped giving money for any measures to improve the parking system. In the first half of 2021, a competition was held to determine the business entities of vehicle parking operators in Ternopil.

In 2019 automatic parking was installed near the NOVUS supermarket on Perlya St. It was done to resolve such situations when the owners have been leaving their vehicles for too long. This parking system saves a lot of

time for car owners due to fast payment through the terminals and high throughput capability.

The development of bicycle transport is one of the elements of ensuring sustainable mobility. Basically, the advantage of bicycles is the absence of need for fuel. But more than that, they also take up little space on the road and during parking, have a positive impact on people's health and remain quite affordable for almost everybody. Moreover, due to the absence of emissions, this type of transport ensures the movement of people without polluting the air. In this regard, the development of bicycle transport is often one of the recommendations provided by transport and climate experts from the European Union. Also, it should be mentioned that the creation of bicycle lanes and bicycle parking improves the life quality of citizens themselves., And this is undoubtedly a significant contribution to the development of European values. With the spread of cycling, noise and chemical pollution will significantly decrease, new resting places will be formed, and cyclists will use much less time and resources during trips to short and medium distances.

Although the number of owners of two-wheeled vehicles is increasing in Ternopil, only 1.5% of movements are carried out using bicycle transport. This indicates that the existing infrastructure does not meet the existing demand. When pandemic-related restrictions were implemented in 2020, a large numbers of residents rapidly moved to bikes. However, due to a clear shortage of bike lanes, most of the users of bicycle transport in Ternopil moves along the sidewalks. By doing so, these bicycle users violate existing traffic rules that clearly prohibit the movement of bicycle transport on sidewalks. Thus, cyclists endanger pedestrians, and reduce the overall safety of movement across the city.

Currently, there are only 8 kilometers of bicycle lanes, which are equipped with pavement and marked with signs of adjacent traffic of both pedestrians and cyclists. Despite the allocation of a bicycle lane in specific color, such signs give the cyclists, as well as the pedestrians, the right to move along the entire sidewalk. This negatively affects the attractiveness of cycling infrastructure and puts pedestrians at high risk.

The city has about 100 bike parks, but there are no bicycle rental stations. Instead, there is a possibility to rent electric scooter from 3 different providers. Owners of lightweight electric vehicles use sidewalks, bicycle lanes and carriageways at their own discretion. Due to the significant difference in speeds, moving along the sidewalk, this transport creates an additional danger to pedestrians. According to the strategic plan for the development of the community, it is planned to construct 100 km of bike lanes and bicycle counterbands and equip 2000 bicycle parking spaces throughout the community by 2029 (Figure 4).

Pedestrian infrastructure is suitable for people with limited mobility only in the central part of the city. Outside the center there are not enough special places for lowering the sidewalk, and in some places there are no sidewalks at all. Along some sidewalks, pedestrian crossings are not marked or they are just located too far from the intersection. For safety reasons, the pedestrian path should not be torn apart by scattered pedestrian

crossings. After all, it provokes pedestrians to shorten the path, which can lead to an emergency. Not all pedestrian crossings in the city of Ternopil are illuminated, but every year the number of such crossings significantly decreases.

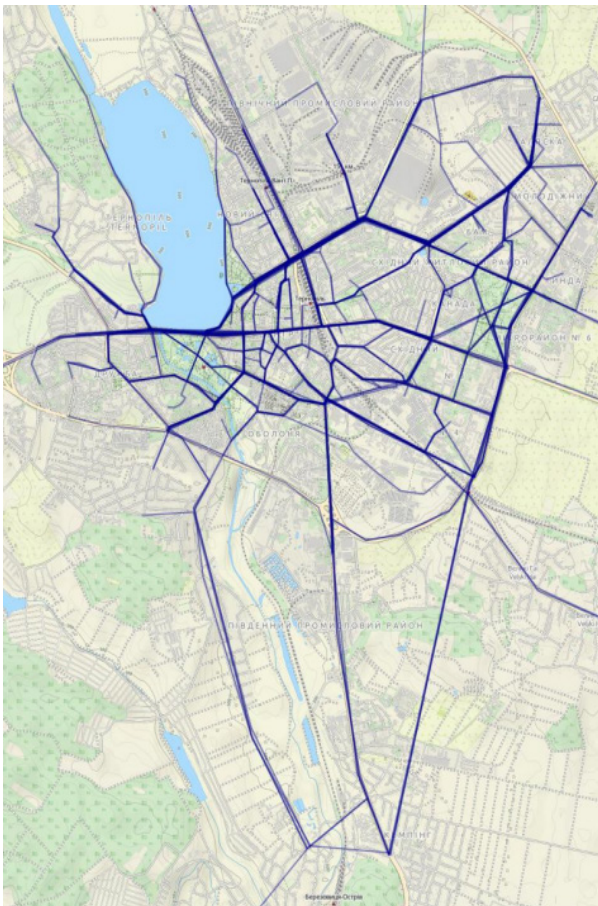


Fig. 4. Bicycle lanes of Ternopil provided by the Strategic Plan

Nevertheless, funds from the local budget are annually allocated for the development of pedestrian infrastructure. Such frequent improvements are the reconstruction of sidewalks, the establishment and overhaul of pedestrian paths, the installation of additional lighting and unregulated pedestrian crossings, the replacement of the pavement with figured paving elements.

In 2020, the nomenclature of pedestrian infrastructure in the city was replenished with a new object - an elevated pedestrian crossing. This elevated crossing connects the Warsaw micro-district with the Park of National Revival and Stepan Bandera Avenue (Figure 5). During the construction of the transition, the needs of people with limited mobility were taken into account. Also, the bridge is equipped with two elevators. This object was erected at the expense of the construction company "Kreator-Bud", with no funding from the city budget. This demonstrates the high efficiency of the partnership between the public and private sectors and stimulates the attraction of funds from private investors in the infrastructure of social importance [4].

Maintenance, repair and renovation of the transport infrastructure throughout the community is carried out by the relevant executive bodies of Ternopil City Council. All these

processes are carried out using the annual planning approach of financing of necessary activities on the basis of approved industry programs. The planned and actual allocations for the maintenance and development of transport infrastructure over the past 5 years have been analyzed on the basis of official data from the Ternopil City Council [5]. In particular, for this analysis, information about financing programs for reforming and developing various spheres of community functioning has been used. Among the analyzed areas are housing and communal services, as well as the development of bicycle infrastructure, urban electric and passenger transport, an automated fare payment system and passenger accounting in public transport. Furthermore, it should be noted that despite various sources of financing, such as the city budget, state budget, variety of investments, loans, funds of individuals and legal entities, the implementation of measures still largely depends on the funds from the local budget.



Fig. 5. Pedestrian bridge on the April 15th str.

Analysis of the allocation of funding and its development (Table 2) showed that for a long time there has been underfunding of works related to the transport infrastructure of Ternopil. For example, the actual indicators of the development of financial resources allocated from the community budget to improve the state of SN for 2020 did not reach the planned indicators by 36.4%. Nevertheless, funds from the state budget in the total amount of 118538.13 thousand UAH were also allocated for the reconstruction of the overpass through the railway track on the Obizna street. According to the data from the community budget for the implementation of the Program activities for the development of bicycle infrastructure in Ternopil for 2020, it was planned to allocate 2000.0 thousand UAH for such innovational processes. But, in fact, there was no funding at all. Actual indicators of financial resources development allocated from the community budget for the improvement of road safety for 2020 did not reach the planned indicators by 64.7%. This result is due to the lack of actual allocations for the marking and installation of traffic limiters that have been provided by the program. Actual indicators of development of financial resources allocated from the community budget for the development of the PT system for 2020 did not reach the planned indicators by 39.2%. There was no funding for the purchase of trolleybuses, overhaul of the fleet and provision of infrastructure for its maintenance.

Table 2. Financing amounts of transport infrastructure measures as part of sectoral programs, thsd UAH

	2018 p.			2019 p.			2020 p.		
	Plan	Fact	Deviation	Plan	Fact	Deviation	Plan	Fact	Deviation
Enhancement of SN	197314,7	113553,3	-83761,4	182010,0	165504,1	-16505,9	210620,0	133899,7	-76720,3
Road Safety Improvement	8100,0	5379,1	-2720,9	8600,0	7702,7	-897,3	15500,0	5465,0	-10035,0
Development of PT system	22190,9	10452,7	-11738,2	50443,4	23869,6	-26573,8	49915,6	30339,8	-19575,8
Development of bicycle infrastructure	1420,0	800,0	-620,0	0	0	0	2000,0	0	-2000,0

3 Conclusions

Summarizing the identified problems, it can be concluded that the maintenance, repair and renovation of the transport infrastructure of the community is carried out by the relevant executive bodies of the Ternopil City Council. In order to perform all these processes, the approach of annual financial planning of necessary activities based on approved industry programs is implemented. Furthermore, it should be noted that despite various sources of financing, such as the city budget, state budget, variety of investments, loans, funds of individuals and legal entities, the implementation of measures still largely depends on the funds from the local budget. Analysis of the allocation of funding and its development showed that for a long time there has been underfunding of works related to the transport infrastructure of Ternopil.

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