FORMING A NETWORK OF INDIVIDUAL CAR PARKING FACILITIES USING THE EXAMPLE OF LVIV CITY

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The escalating levels of motorization in Ukrainian cities, with over 200 cars per 1,000 inhabitants, have given rise to significant environmental, social, and economic challenges. The lack of adequate parking facilities makes these issues worse, particularly, in historically formed cities such as Lviv, where the architectural and planning structures were not designed to accommodate.Parking Demand. There is no precise data on the exact level of motorization in Lviv. To calculate it, the average level of motorization in Ukraine as of 2016 is taken, which amounts to 202 cars per 1,000 population (AUTO-Consulting 2016). The population of Lviv in 2016 was 758,500 (Main Department of Statistics in Lviv Oblast 2017). Therefore, the estimated demand for parking spaces for the permanent storage of individual motor vehicles in Lviv's population amounts to 153,217 parking spaces.

Existing Number of Parking Spaces. Using the developed methodology for calculating the number of parking spaces based on OpenStreetMap geospatial data (OpenStreetMap contributors 2018), it was determined that the number of parking spaces within the administrative boundaries of Lviv is approximately 63,545 (excluding multi-level parking and street parking). Therefore, the calculated provision coefficient for residents' parking spaces is 0.41 (63,545 parking spaces for 153,217 resident vehicles). The parking infrastructure consists of the following elements:

- Garages with a total area of 445,427 square meters (~17,817 parking spaces), accounting for 28% of the total number of parking spaces.
- Parking lots (open parking areas) with a total of 45,728 parking spaces (72% of the total), including: polygons with an area of 944,078 square meters (~37,763 parking spaces); and lines with a length of 33,851 meters (~7,965 parking spaces).

The parking infrastructure in Lviv consists of the following elements: on-street parking; parking lots (surface parking areas with security); single-level garages organized in cooperatives. Underground and multi-level parking facilities are present only in specific new residential complexes and public facilities, and are not intended for public parking. The city does not have public multi-level underground parking lots of the "park and walk" type, or park and ride facilities, despite being included in Lviv's existing master plan from 2008 (Dubina et al. 2008) and outlined in the investment project program (Rusanova and Sosnova 2009).

Geographically, garages and most parking lots are located on the periphery of the city, near the first transport ring in areas developed during the second half of the 20th century. Paid parking lots and garage boxes in cooperatives in the central part and on the outskirts of Lviv are intended only for the permanent storage of motor vehicles. Temporary and short-term visitor parking mainly occurs on street parking lots or informally.

A significant percentage of the city's territory occupied by parking facilities belongs to garages (28% of the total number of parking spaces). Considering the absence of multi-level garages in Lviv, this indicates inefficient use of the city's land. In the absence of parking space availability for the permanent storage of vehicles and the lack of vacant areas for constructing new parking lots, single-level, architecturally unattractive garage cooperatives should be considered as territory reserves for multi-level parking.

Due to functional concentration in the overall city's historical center, "park and walk" parking facilities should meet the temporary and long-term parking needs. However, there are only three parking lots of this type in the city center, with a total of 186 parking spaces. Two of them are dedicated to paid parking on the streets within the historical core of Lviv: 1) a parking lot on Valova Street; 2) a parking lot within the streets of Virmenska, Teatralna, Lesi Ukrainky, and Nyzky Zamok (Lviv City Council 2018a).

Based on theoretical principles, the evolution of the planning structure of historically formed cities, and modern practices, the main approaches to the

development of a balanced urban transportation system in a historically formed city have been formulated. These approaches serve as prerequisites for the formation of a parking network and include: 1 - optimization of the road network; 2 - decentralization of the overall historical city center; 3 - expansion of the public and bicycle transportation network and ensuring their mobility; 4 - development of comfortable and safe pedestrian communications; 5 - reducing car presence in the historical part of the city (Table 5.1.1). These enumerated approaches directly or indirectly reduce the need for parking facilities in the historically formed part of the city, prioritizing the development of sustainable modes of transportation. Let's consider them in more detail.

Optimization of the road network. The approach involves: a) improving the planning organization of the road network (transport rings, radial connections); b) traffic organization (relocating transit highways of national significance from the central zone of the city, creating duplicate routes, one-way streets in the central part of the city); c) optimization of technical parameters of road network elements (optimizing the cross-sectional profiles of streets - width of carriageways, sidewalks, bicycle lanes, etc., improving transportation interchanges, replacing pavement, etc.).

Ring roads have been constructed in many historically formed European cities that have faced the challenge of expanding the city area and served to alleviate traffic congestion and increasing intercity transit. They influence the development of the spatial structure of the city by creating nodes and intensifying commercial, residential, and industrial areas near the intersection of radial and ring roads. By reducing overall traffic through the city center, ring roads contribute to the formation of new sub-centers on the periphery, resulting in improved mobility in these areas.

One of the peculiarities of the road network in historically formed cities is the narrow width of streets in the city center, which necessitates rational traffic organization. It has been proven that one-way traffic on short and narrow streets with a high level of transportation load is more efficient than two-way traffic (Ortigosa et al., 2017). The organization of cross-sectional profiles of streets also has a significant impact on the functioning of the road network, and improper planning can contribute to complications in transportation and pedestrian movement. For example, improper

placement of on-street parking within the cross-sectional profile leads to a decrease in street capacity (Zagorui, 2007; Lobashov, 2010), and designing excessively wide carriageways often does not contribute to increased traffic flow but reduces pedestrian comfort due to narrowed sidewalks and green areas (Drexler, 1928; Schiller et al., 2010).

The experience of reconstructing the road network in historically formed cities within this study was examined using the examples of Leipzig and Krakow. It was found that improving the planning organization of the road network in these cities involves the formation of four ring roads that, through measures restricting access to the central part of the city, divert transit traffic and improve urban mobility. Traffic organization involves directing transit flows to the outskirts of the city, while the central part develops a network of one-way streets. The optimization of technical parameters of road network elements in the studied cities is carried out with the priority given to public transport, pedestrian, and cycling movement.

Justification of recommendations for the formation of a parking network in Lviv can be determined by analyzing the city's characteristics. A comparison of the differences in urban planning organization of the transport network and parking facilities in Lviv, Leipzig, and Krakow, as examined in the study, is presented in Table 5.3.1. According to the research methodology and city comparisons, it has been determined that the modern development of the functional and planning structure, transport network, and parking facilities in Lviv significantly lags behind in most parameters.

As evident from the table, a crucial factor in formulating recommendations for the formation of a parking network in Lviv is that despite having the same population as Leipzig and Krakow, Lviv's population density is more than twice as high. This necessitates a more efficient optimization of the road network and the development of highly mobile and passenger-friendly modes of public transportation. Simultaneously, more stringent restrictions on car usage within the historical part of the city need to be implemented. It is justified that only by simultaneously discouraging car usage and promoting the development of alternative transportation modes can a balanced

transport system be achieved (Vuchyk, 2011). Given the high population density and urbanization in Lviv, these measures should be twice as effective.

Twice the population density of Lviv, half the length of the road network per resident, and half the level of motorization, which is trending upward, reflect that the number of cars in Lviv has reached critical levels where normal functioning of the transport system becomes challenging. Considering the challenges in the development of Lviv's transport network, optimization measures for the city's transport system are urgent.The parking network, as the most sensitive element of the city's transport system (Banister, 1995), can contribute to the development of a balanced transport network in Lviv under the condition that parking within the historical part of the city is limited, and parking facilities for residents' vehicles are mainly located on the outskirts of the city. Based on the formulated prerequisites for the formation of an optimal parking network in historically formed cities, it is advisable to implement a set of measures in Lviv that take into account the city's characteristics

Optimization of the road network. Considering the experience of developing four transport rings in historically formed cities, it is necessary to establish the II transport ring in Lviv, which will enable bypassing the central part of the city, alleviate traffic congestion, and allow for further expansion of pedestrian zones. The plans for the formation of the II transport ring were initially laid out in the first Soviet general plan in 1940 (Kasyanov, 1940) and have remained relevant (Lyubitsky, 2017a; Rusanova & Sosnova, 2009; Tupis & Lyubitsky, 2016). The effectiveness of organizing the II transport ring is justified by the fact that in the examined cities (Leipzig, Krakow), the main traffic congestion occurs on the second ring, whereas in Lviv, it occurs on the I transport ring surrounding the historical core ("ring road"). The eastern segment of the II ring should coincide with the north-south chord connection, which is included in the current master plan (Dubina et al., 2008). Considering the complexity and feasibility of implementing the distant perspective of the chord, it is necessary to alternatively route a temporary section of the ring through existing streets. Optimization of the III ring should involve extending Luhanska Street to Siaivo Street and improving the cross-sectional profiles. Completion of the planned northern segment of the IV circular road

will prevent intercity transit through the city center. International and national highways that currently pass through the historical center should be relocated to the III and IV rings, ensuring fast transit traffic.

The proposed recommendations for the development of an optimal parking network in Lviv are possible under the condition of transforming the functional-planning structure, optimizing ring roads, and functionally decentralizing the historical city center. It requires the development of high-mobility and high-capacity public transport modes such as trams and urban railways. Considering the threshold values, the development of new parking facilities is advisable primarily on the outskirts of the city. Volumetric and spatial solutions for garage design in the historical area of the city should take into account the proximity to valuable architectural heritage sites. The implementation of the parking network model in Lviv should be phased and fully achievable by adjusting the Ukrainian regulatory framework.

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THE HISTORY OF THE DEVELOPMENT OF LOGISTICS

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