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METHODS FOR ASSESSING THE TRANSPORT AND PEDESTRIAN ACCESSIBILITY OF MULTI-STOREY RESIDENTIAL BUILDINGS AND COMPLEXES, AS WELL AS THEIR IMPACT ON THE CITY INFRASTRUCTURE

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Astract. The paper focuses on the author's method of assessing pedestrian and transport mobility of residents of modern multi-storey buildings and complexes. The study of transport routes in cities is the subject matter of entire scientific and design institutes, therefore, the method has been designed to make architects, researchers, developers and urban planners aware of a housing unit in terms of its accessibility, as well as to assess its impact on the city.

Key words: multi-storey buildings, transport mobility, urban planning, residential complexes, new housing units.

Problem statement

Currently, in Lviv, there is a rapid development of housing construction. During 2020–2021, 185 residential complexes were commissioned in the Lviv region, 104 of which – within Lviv, and another 39 – in the thirty-kilometre zone around the city (LUN, 2021). Despite the development of post-industrial areas in the middle lane of the city, as it is specified in the Concept of Spatial Development of Lviv (Institute of the City, 2019a), most new housing units are situated on the outskirts of the city. Given the number of high-rise buildings, as for Lviv (about 10 floors on average), in these areas, there are dense formations that require infrastructure for their service. First of all, it concerns transport infrastructure, given the monocentricity of the city and the radial structure of the planning city structure (Mazur, Korol, 2018).

It is required for urban research to respond quickly to changes, so that modern assessment methods need to be dynamic and adaptive. At present, no method would assess the accessibility of the object and its interaction with the transport infrastructure of the city without specialized studies. The paper is focused on creating such a method based on open, adaptive data with the ability to include new variables within the system.

Analysis of recent research and publications

Urban housing covers architectural, urban, economic, social and transport aspects. The number of cars in the cities of Ukraine is growing (Autoconsulting, 2019), and the current urban environment does not allow to increase the capacity of roads for motorists. Habrel M. (Habrel, 2020, 2004), Cherkes B. (Cherkes, Farenchuk, 2020) studied the issue of the approach to housing construction in large cities of Ukraine. Krystofchuk M. (Krystopchuk, 2021) Gits I. (Gits, Zhuk, Pivtorak, 2020), Wall E. (Wall, Waterman, 2009), Hunt, J. D., (Hunt, Kriger, Miller, 2005) tackled the city mobility issues.

Objective of the article

The objective of the article is to outline the method for assessing the quality of mobility for high-rise residential buildings in Lviv, built during 2020–2021, as parts that interact with the existing transport infrastructure of the city. The technique may further be used in studies of similar relationships in other cities. The set of data considered in the study can be used both by the city authorities to develop a strategy for housing development, and by specialists for a more detailed analysis of a particular complex in terms of its place within the urban mobility structure. The author's method of assessing the interaction of high-rise residential complexes with the transport structure in the example of Lviv is demonstrated for the first time in the paper.

Results and discussions

While conducting the study, data on 30 multi-storey residential complexes (average height of more than 7 floors) were analyzed (Fig. 1). As the average number of storeys in Lviv is only 3 storeys, 7-storey buildings can already be considered high-rise in the context of urbanization. The selection criteria, in addition to the number of storeys, were the number of inhabitants (>100 people), location within the city and new construction (rather than reconstruction of current buildings). The following were selected for the analysis: 1 residential complex in Lychakivskyi district; 2 – in Halytskyi district; 3 – in Zaliznychnyi district; 8 – in Shevchenkivskyi district; 9 – in Frankivskyi district; 7 – in Sykhivskyi district. Compared to other districts, in Halytskyi and Lychakivskyi districts, there is the largest part of historic housing and a smaller potential area of a plot for construction. That is why only a few complexes fell under such categories. Instead, multi-storey residential buildings from Shevchenkivskyi, Sykhivskyi and Frankivskyi districts formed the basis of the study at the expense of the territories of the former country and garage cooperatives (“Malogoloskivski Pahorby”, Pid Holoskom Street, 8, Varshavska Street, 201a, Residential Complex “Continent”, Residential Complex “Pasichnyi”, etc.), another part – at the expense of post-industrial areas (Residential Complex “Parus City”, Heroiv UPA Street, 73, Uhorska Street, 14, etc.).

Only 3 high-rise buildings from Zaliznychnyi district were included in the sample due to the predominant manor buildings and the significant influence of the railways. According to the data (LUN, 2021), in Halytskyi district only 3 residential complexes were commissioned during 2020–2021: in Lychakivskyi district – 18, in Zaliznychnyi district – 14, in Sykhivskyi district – 27, in Frankivskyi district – 12, in Shevchenkivskyi district – 30. Only 3 out of 57 high-rise buildings of the city are located in Lychakivskyi district, 2 – in Halytskyi district, 5 – in Zaliznychnyi district, 20 – in Sykhivskyi district, 6 – in Frankivskyi district and 21 – in Shevchenkivskyi district. Frankivskyi district of the city gained a significant place within the sample due to the high concentration of new housing construction during 2015–2019. The sample of the study, according to its data set, reflects the market trends typical for Lviv over the last five years.

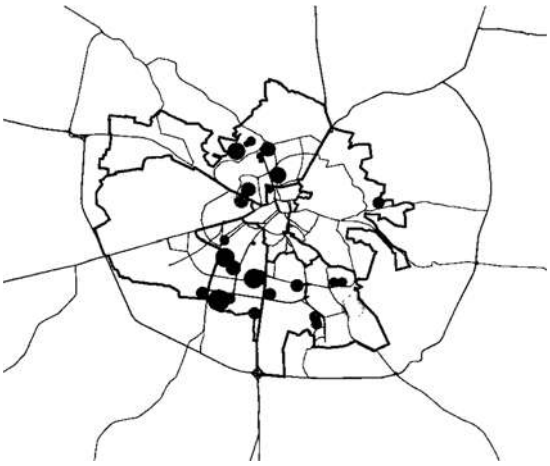

Fig. 1. Map of the studied multi-storey residential buildings or complexes

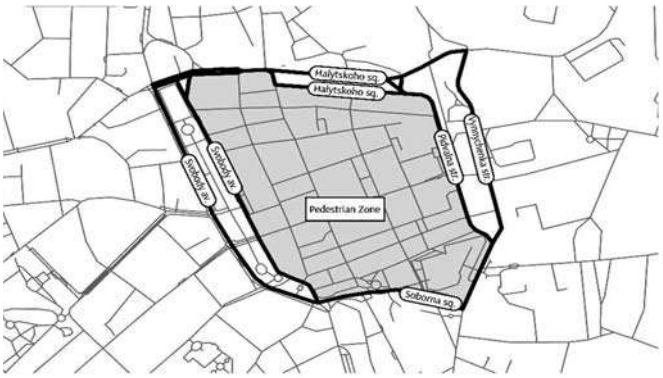

Fig. 2. Map of the nearest roads to the center of Lviv

According to a study by the Institute of the City (Institute of the City, 2019b), 18 % of the Lviv population prefer walking on foot, 52 % – by public transport, 6 % – by bicycle, and another 23 % – by own car. In agreement with the plan of sustainable urban mobility of Lviv (Mobility of Lviv, 2019), the priority of traffic within the city is given by the following principle: pedestrians – public transport – cycling – logistics and delivery – cars.

That is why the first criterion for assessing accessibility was the time of walking on foot. This is not the most important part of the population, but this criterion, first of all, characterizes the distance of a complex from the average destination and also includes an estimate of the path for cyclists (6 %) and those using other means of transport (e.g, scooters – 1 %). The low provision of the city with bicycle infrastructure does not allow to consider routes taking into account cycle lanes as a separate unit of research. However, for the studies of other cities with developed cycling, the assessment of cyclists' movement in the city can be introduced as an additional parameter.

Proximity to the geographical centre of the city, tourist flows, location of office buildings, as well as the concentration of public functions creates a usage disparity of urban space towards the historic core, namely, the area included in the UNESCO list. Therefore, within the assessment of pedestrian accessibility as a starting point, the city hall was chosen as the average value of the endpoint of movement from all surrounding areas of Lviv.

As the central part of the city is accessible only to pedestrians, the distance to the nearest street, square or avenue to the pedestrian zone is chosen for transport accessibility (within the ring of Pidvalna Street – Danylo Halytskyi Square – Ivan Honta Street – Yaroslav Osmomysl Square – Svoboda Avenue – Mickiewicz Square – Halytska Square – Soborna Square – Mytna Square) (Fig. 2). Data on congestion on the way to the centre are obtained from the open data of Google Maps and QGIS of normal loading at the rush hour – on Mondays and Fridays, 8 to 10 am and 5 to 7 pm.

The next step of the study is to calculate the median value of the path load for each of the hours, and then – the average between all the studied hours. In the morning, the path from the dwelling to the centre was chosen for the study, and in the evening, on the contrary, from the ring-forming streets around the centre to the corresponding building. The result is distributed in points from 0 to 8, where 0 is the absolute absence of congestion, and 8 is the continuous congestion of roads. All studied apartment blocks were in the range from 4 to 5.5 points of the average value of congestion in the corresponding hours, which shows a relatively high level of congestion in the city as a whole (Fig. 3 and Fig. 4).

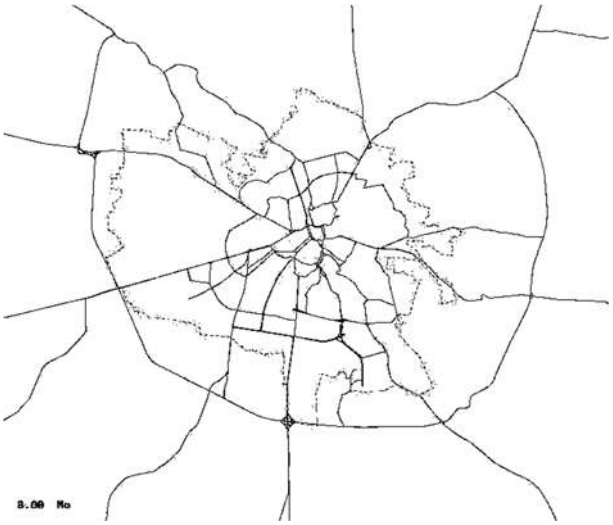

Fig. 3. Traffic jam map of Lviv (Usual congestion as for Monday, 8 am)

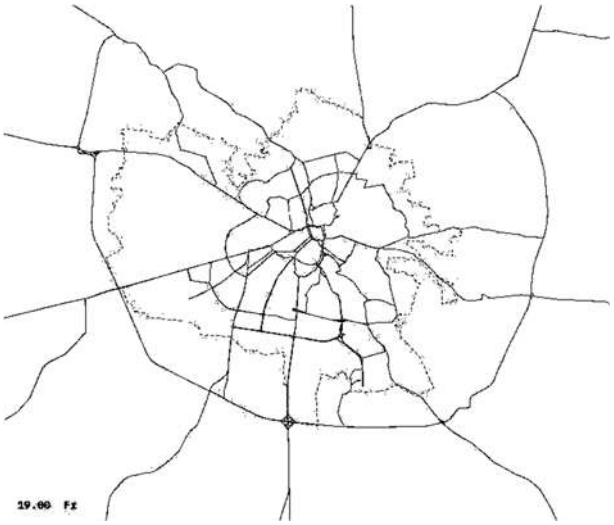

Fig. 4. Traffic jam map of Lviv (Usual congestion as for Friday, 7 pm)

In the study, the following means of transport are taken into account: trams, trolleybuses and buses (small and large). To assess transport accessibility, 2 parameters were chosen: the duration of the pedestrian path from the median point of the residential complex to the nearest stop (Fig. 5) and the frequency of departure of all means of transport from the corresponding stop. For the convenience of information processing and its display, these parameters were systematized into an overall score according to an 8-point scale, where 3 points – for walking time to stop, and another 5 – the interval of traffic, which is determined using OpenStreetMap and EasyWay. The time to stop is divided as follows: up to 5 minutes (0–1 b), 5– 10 minutes (1–2 b), 10–15 minutes (2–3b). The interval of public transport from each stop is distributed as follows: up to 2 minutes – 1 point, from 2 to 4 minutes – 2 points, 4–7 minutes – 3 points, 7–15 minutes – 4 points, more than 15 minutes – 5 points. When exploring other cities, those that do not have public transport in Lviv, as well as the subway, city train, water means of transport, etc., can be included.

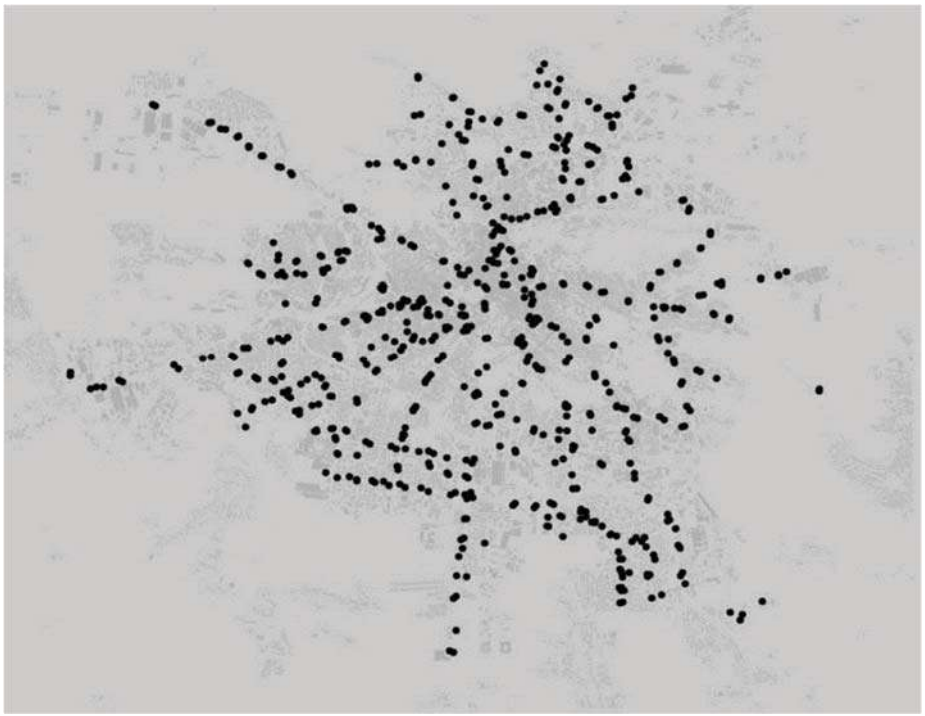

Fig. 5. Map of the public transportation stops in Lviv

An important criterion in the method is the estimated number of inhabitants, calculated for each complex in accordance with the total area of apartments in the complex or house and the average number of living space per person in Lviv. It is this criterion that determines the level of interaction of a particular housing with the infrastructure of the city.

The result was a comprehensive two-way assessment, which allows observing both the interaction of the city with a building and buildings with the city in terms of accessibility and load on infrastructure (Fig. 6).

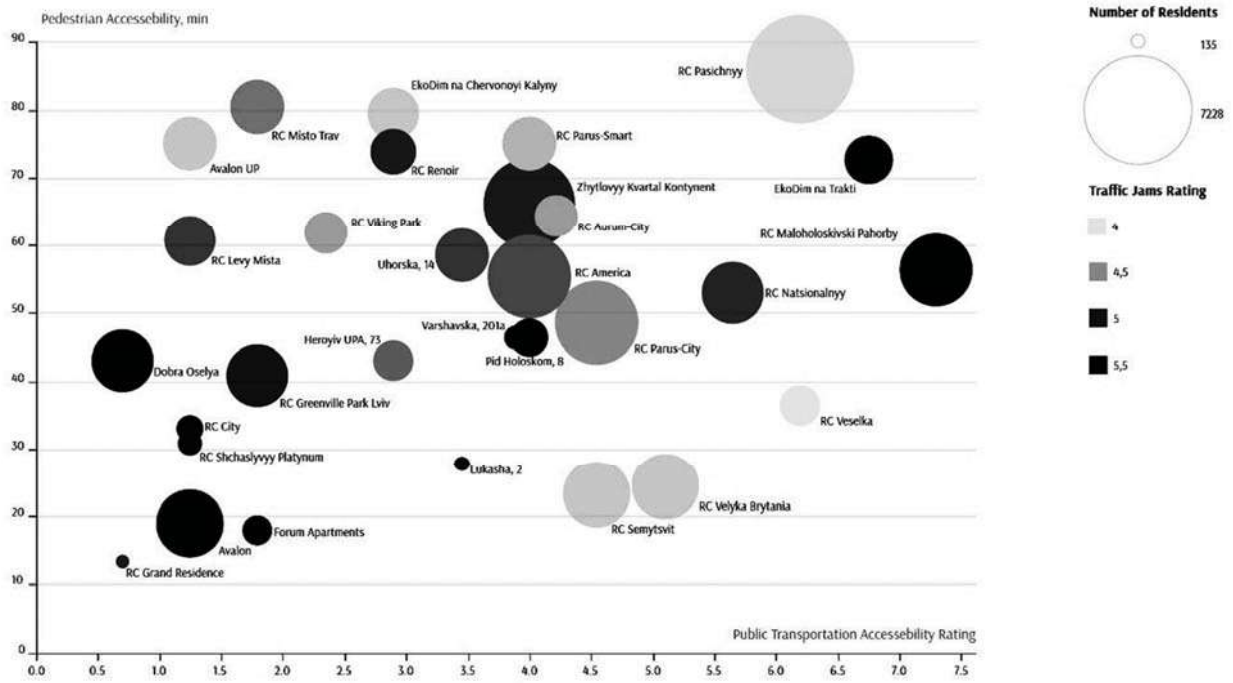

Fig. 6. Overall urban mobility graph for multi-storey housing in Lviv

The closer the building is to the coordinates on the graph, the better its accessibility of public transport and pedestrian mobility. The colour of the circle is responsible for the average congestion on the car path, and its size indicates the number of inhabitants of each complex. Buildings and complexes with more residents have a more significant impact on the city's infrastructure. The impact rate also is supplemented with the congestion survey results. This helps to make an overall rate of the building or complex, as with the rising number of residents in it, more capability of the routes is needed to meet the new transportation reality of the block, street, or district. Thus, the ideal option for multi-storey housing would be a light circle of small diameter close to the coordinates, as it has a short distance to the centre, good access to public transport and low congestion during rush hours with a small number of residents.

Residents have more options to reach any point within the city closer building is to the historic core. On the other hand, complexes that appear on the territory of the former country and garage cooperatives not far from the outskirts of the city (distance to the centre – about 6–7 km (65–80 minutes walk)) are poorly provided with the current public transport infrastructure. That is why their residents are made to rely on cars, which significantly increases the load on the current road network of the city. Thus, areas with congestion remain not only at the entrance to the city centre but also the exit to the main district roads (Malogoloskivska Street, Pancha Street, Volodymyr Velykyi Street, Antonovycha Street, Sykhivska Street, Stryiska Street, etc.). The average level of congestion on the way to the centre is not so high compared to the residential complexes occurring on the site of the former industrial ring of the city. Although, it should also be noted that all these complexes are not yet fully populated and the situation may change significantly shortly. More details on the data of the selected high-rise residential buildings can be found in Table 1.

Table 1

Statistics on the residential complexes of Lviv

RC name	Number of residents	Pedestrian accessibility, min	Public transportation accessibility	Traffic jam rating
Avalon	2744	22	1,5	5,33
Dobra Oselya	2365	44	1	5,4
RC Semytsvit	2751	26	4,5	4,4
RC Velyka Brytania	2893	27	5	4,4
RC Veselka	1065	38	6	4
RC Parus City	4453	49	4,5	4,5
RC Natsionalnyi	2354	53	5,5	4,75
Uhorska Street, 14	1818	58	3,5	4,67
Avalon UP	1722	73	1,5	4,4
Pid Holoskom Street, 8	828	47	4	5,5
EkoDim, Chervona Kalyna	1700	77	3	4,4
RC Shchaslyvyi Platynum	369	33	1,5	5,25
Forum Apartments	505	21	2	5,33
RC City	450	35	1,5	5,25
RC Maloholoskivski Pahorby	3250	56	7	5,5
RC America	4224	55	4	4,65
RC Viking Park	1187	61	2,5	4,48
EkoDim, Trakt Hlynianskyi	1430	71	6,5	5,3
Varshavska Street, 201a	344	47	4	5,5
RC Greenville Park Lviv	2329	42	2	5
Heroyiv UPA Street, 73	1068	44	3	4,58
RC Misto Trav	1894	78	2	4,50
RC Levy Mista	1641	60	1,5	4,67
RC Parus Smart	1880	73	4	4,42
RC Pasichnyy	7228	83	6	4,33
RC Kontynent	5322	65	4	4,92
RC Renoir	1283	72	3	4,92
Lukasha Street, 2	172	30	3,5	5,17
RC Grand Residence	135	17	1	4,92
RC Auroom City	1112	64	4	4,48

Conclusions

The study of multi-storey or dense residential complexes can not be conducted without taking into account the peculiarities of their interaction with the already formed urban environment. One of the issues

of the historic cities of the post-socialist countries was the problem of transport and mobility due to the rapid increase in motorization and the elimination from the industrial vector of urbanization, under which the public transport system was sharpened.

The method outlined in the paper is an opportunity to adapt the system of calculating the transport structure of the city for conducting urban studies without specific data used by specialists in transport systems.

Gradual implementation of the method involves the following:

1. Determining the time of pedestrian accessibility to the city centre;
2. Defining the level of congestion on the way to the centre from the residential complex in the morning and the return trip in the evening;
3. Measuring the distances to the nearest public transport stops (tram, trolleybus, bus, etc.);
4. Specifying the interval of public transport;
5. Subtracting the total area of the complex. Defining the number of inhabitants.

The application of the method on the example of Lviv allowed us to assess the mobility of residents of multi-storey residential complexes and buildings. Due to the obtained data, it is possible to predict the dynamics of mobility and congestion of streets in some parts of the city, as well as to identify problems of existing high-rise residential buildings and complexes, or to create a rationale for the prospects of design and construction.

Establishing trends in housing development, in particular multi-storey residential buildings, and comparing the results with similar indicators in other cities are the objectives of further research.

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МЕТОДИКА ОЦІНЮВАННЯ ТРАНСПОРТНОЇ ТА ПІШОХІДНОЇ ДОСТУПНОСТІ БАГАТОПОВЕРХОВИХ ЖИТЛОВИХ БУДІВЕЛЬ І КОМПЛЕКСІВ, А ТАКОЖ ЇХНЬОГО ВПЛИВУ НА НАЯВНУ ІНФРАСТРУКТУРУ МІСТА

Анотація. *Дослідження висотних та щільних житлових комплексів не може відбуватися без врахування особливостей їхньої взаємодії із сформованим міським середовищем. Через різке зростання автомобілізації населення та відхід від індустріального вектору розвитку міст, під який узгоджено систему громадського транспорту, однією з найнагальніших проблем історичних міст постсоціалістичних країн стала проблема мобільності.*

Представлено авторську методику оцінювання пішохідної та транспортної мобільності мешканців сучасних багатоповерхових будівель та комплексів. Дослідження міського середовища мають швидко реагувати на зміни, тож сучасні підходи до оцінки середовища повинні бути динамічними та адаптивними. Методику, якуу окресленоу статті, створено для того, щоб її розглядали архітектори, дослідники та містобудівники житлового утворення з погляду його доступності, а також оцінюванння впливу цього утворення на місто.

Застосування методики дало змогу на прикладі Львова отримати дані про транспортну та пішохідну доступність для мешканців 30 багатоповерхових житлових будинків та комплексів, побудованих протягом 2015–2021 років. Завдяки аналізу цих даних можна спрогнозувати динаміку пішохідної мобільності та завантаженості вулиць транспортом на окремих ділянках міста, а також виявляти проблеми наявних щільних і висотних житлових утворень, чи створити обґрунтування для проектування нових.

Окреслення тенденцій розвитку висотного житлового будівництва з погляду мобільності та порівняння отриманих результатів із аналогічними показниками інших міст є завданнями подальших досліджень.

Ключові слова: *багатоповерхове житло, транспортна мобільність, містобудування, житлові комплекси, нові житлові утворення.*