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Kinetic model in the agglomeration design: on the example of Lviv

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Abstract. The kinetic components of local settlement systems with implemented processes related to the movement of people, materials, energy, information, etc. are studied. A kinetic model of the organization and controlled development of local settlement systems is proposed, which is built on the knowledge of movement theories and the properties of space associated with them and provides an opportunity to organize connections between its subsystems and elements of various spheres. The nature of kinetics (movement) in urbanized systems is concentrated in the systems' processes, events, and behavior. Their study and modeling are accompanied by the analysis of phenomena that occur from the point of view of time (presented in the form of a function where time is independent), as well as random events, which by their nature are poorly predicted. The provisions of the kinetic model are applied to the analysis, evaluation, and justification of the concept of spatial organization and development of the local settlement system "Great Lviv". The prospects of Lviv as an agglomeration in the system of connections and relations with the environment are revealed. The requirements for development and conceptual proposals for the optimization of movement within the agglomeration are substantiated. It is defined that requirements and proposals should be oriented toward the search for solutions that reveal the uniqueness of the city space and its surroundings, ensure the harmonious integrity of the agglomeration, and the practical "mounting" of communication functions into the structure of the space.

Keywords: methodology of urbanism, kinetic model of urbanized system development, spatial planning

Introduction

The system of spatial planning and urban planning in Ukraine is characterized by the inconsistency of national, regional, and local scales of planning, design, and decision-making: the hierarchy of the system has been destroyed; there is no agglomeration planning, competing "perspectives" between communities of urban, suburban, supra-urban and regional scales are sharpening. There is a demand to go beyond the existing confrontations between systems of different levels, to improve the methodological foundations of the development of concepts, strategies, and urban planning documents in institutional, cultural, social, ecological, and economic contexts, and to develop practical recommendations for their implementation. Urban development processes can be understood with the help of theoretical provisions that combine the dynamics, kinetics, and connections of places. The same provisions can be used to identify types of cities and to distinguish urban phenomena from the rest of social reality. Urbanized systems are primarily functional connections, social communications, and relationships. In the conditions of globalization and the dynamization of processes in cities, kinetics (connections to movement) becomes a fundamental category in the methodology of urbanism and requires in-depth research. This problem is especially acute within urban agglomerations and local settlement systems of large cities.

The purpose of the article is to reveal the phenomenon of displacement as social-mass-energy-information integrity in the space of urbanized systems; substantiate the kinetic model and ways of local settlement system development on the basis of kinetics. The kinetic model of the organization and controlled development of local settlement systems is built on the knowledge of theories of movement and the related properties of space and makes it possible to organize connections between subsystems and elements of different spheres to increase the efficiency of resources, energy and information transfer in the network, which as a result will affect the validity of project decisions.

Theoretical prerequisites of kinetics analysis for tasks of urbanism and spatial planning

The kinetic model of local settlement system development was based on the evolutionary theory of urban systems [5; 8; 15; 20; 24, p. 94–117]; models of city development as a complex system [6–7; 10; 14; 25], using analogies with the laws of kinetics, dynamics, and thermodynamics as a science of movement, motion, and energy [2; 12; 21; 26]. The analysis of kinetics (movement, dynamism, impulse, etc. in urban planning, regional planning, and agglomeration design) requires certain abstractions and generalizations of in-depth understanding with an orientation to professional tasks.

The urbanized system is an open hypersystem that exchanges energy, matter and information with the environment [16]. The main idea of urban planning is to create order out of disorder by improving processes and interactions between elements in the system and with the environment at different levels [1; 3–4; 22]. The main properties of such systems are openness, nonlinearity, dissipativeness. Open systems are supported by the continuous inflow of substances, energy, and information from the outside. There are non-linear situations and dependencies when joint actions of individual factors lead to effects that have nothing to do with the results of their action separately. The dissipativeness of systems (scattering) is associated with energy losses, part of which is transformed into other types of energy over time, the transition of part of the energy from an ordered to an energy-disordered process. In order to substantiate the set of indicators and characteristics of the space in local settlement systems, where movements take place, the position of multidimensionality of the urban planning space was used, and the indicators of urbanized systems were structured in a five-vector space: "human – H, functions – F, conditions – C, geometry – G, time – T" [9].

The movement in urbanized systems is a function of these five groups of variables. The first group of characteristics concerns a person, his trips and includes needs, priorities, and opportunities; the second group is the conditions of movement (restrictions, obstacles, means, requirements for movement); the third is geometries of movement systems (settlement, centers of gravity, remoteness, development of networks); the fourth is the time characteristics of movement (speed of movement, duration of cycles, synchronization of connections, the intensity of movement); the fifth group includes movement functions such as transit (external), internal, infrastructural coordination of functions, functional stability. The structure of the elements and double interactions of the space, where the processes of people's movement and their needs are realized, are systematized in the table.

The paired combinations of HC spatial interactions relate to the conditions of movement, their comfort and safety. The indicators of population density, anthropometric features of territory development, distances of people's movement in space are evaluated in the HG plane. The combination of HT characterizes the dynamics of the quantitative characteristics of the human dimension (population growth, migration), the average age and age structure of the city's residents; the analysis of trends is carried out and changes in the characteristics of human potential are predicted for the future.

TABLE 1

Characteristics and paired interactions of space dimensions of local settlement systems

Vectors and interactions	**Content of measurements and characteristics of their interactions**
H (human dimension)	structure, goals, needs, priorities, opportunities
F (functions)	of movements to production, service and recreation, transit and internal, consistency of functions, functional stability
C (conditions)	natural, resource, means, conditions, requirements, restrictions, obstacles
G (geometric characteristics)	network development, distances, configuration, settlement, gravity centers
T (time dimension)	cycle duration, speed of movement, synchronization of connections, intensity of movement
HF	functional needs of different groups of people, employment of the population, efficiency of functions, functional adequacy
HC	people's movement conditions, safety, condition and facility use, quality of service
HG	density, distribution of the population on the territory, distances of movements to the gravity centers
HT	social dynamics, movement dynamics, time priorities, changes in needs
FC	conditions and resources for the implementation of functions, technological level, technological influences
FT	productivity, functional dynamics, infrastructure development level, functional stability, timeliness of service provision
FG	functional development of the territory, functional structure of the territory, length of the networks, development of connections with the center, diversity of networks
CG	distribution of movement conditions, geometric characteristics of the territory, special traffic regime zones
CT	movement condition dynamics over time, movement intensity, movement condition stability
GT	change of geometric characteristics of the network over time, networks stability

The level of functional use of the available potential and resources, requirements and restrictions, as well as the level of man-made impacts on the environment is assessed in the FC plane. The availability and quality of communication routes and communication networks, the transit of the territory and the level of functional infrastructure development are the most important conditions for the effective functioning of urbanized systems. The FG interaction is characterized by the functional structure of the territory, the location and size of

functional zones, the scale of various communication systems.

Triple combinations of vectors outline the three-dimensional space of component interaction, them it is possible to characterize people's working conditions, labor and material resources of a certain functional area; population employment dynamics; conditions of people's movement in the process of functional implementation; structural allocation of attraction objects; dynamics of employment and people's trips; the state of resources and conditions for realizing needs; dynamics of functional conditions and resources; changes in functions in space; dynamics of settlement; changes in living conditions.

Quadruple interactions of the five-dimensional urban planning space mean the fixation of one of them. When fixing, for example, the measurement of time, the spatial situation is evaluated at a certain fixed moment. The fixation of other dimensions gives the characteristics of social, demographic, functional processes in the urban complex and an opportunity to assess their consequences. The full set of characteristics of space and urban planning tasks is formed in a five-dimensional combination and is evaluated by an integral indicator of social-ecological-economic efficiency of movements, which includes indicators of usefulness, economy, environmental friendliness and safety of processes.

The kinetic model of local settlement systems

The kinetic model for the study and organization of movements in the urbanized system space reveals the essence of social-mass-energy-informational processes [2; 18; 23]. The nature of kinetics (movement) in urbanized systems is concentrated in the processes, events and behavior of the systems. Their study and modeling are accompanied by the analysis of the phenomena that occur from the point of view of time (presented in the form of a function where time is independent), as well as the study of random events, which are poorly predicted by their nature. We will single out the requirements for the kinetic model of the urbanized systems development: 1) the consideration of kinetics as a holistic process associated with social-mass-energy-informational movements in urbanized systems; 2) the approach should be based on fundamental and objective laws of motion; 3) the connection with the study of the specificity of processes and events in urbanized systems; 4) the orientation of the model to the task of spatial planning and interpretation of it as a tool for optimizing the space of social activity; 5) identification and symbolization of model elements have to reveals the relationships between the properties of spatial dimensions and the characteristics of kinetics (movements).

The model is structurally logical in form and includes indicators of movements (kinetics) in urbanized systems: distance, speed, acceleration, trajectory, mass (volume), force, momentum, inertia, entropy, flow density, elasticity (flexibility), stability, polarization, self-organization, uniformity of distribution, transient processes, diffusion, attenuation, disturbance. The kinetic properties of space are divided into groups that characterize: 1) movement flows; 2) migration processes. The model is built to regulate the development of local settlement systems and coordinate the interaction of movement characteristics with the properties of space. The properties of the space of urbanized systems as hypercomplex systems are structured and summarized in terms of dynamism, flexibility, uniqueness, high information content, energetic, poor predictability, openness to the environment, manageability, evolutionary impulse behavior, homocentricity, entropy, purposefulness, ability to self-organize.

The kinetic model is presented in the form of a multidimensional matrix, the dimension of which is determined by the number of its elements, and the number of cells corresponds to the number of paired combinations. The model aims to reconcile spatial and movement characteristics both within the system and with the supersystem. With a relatively small size (we used 40 elements), the matrix was assembled manually. For matrices with large dimensions and a larger amount of information in the cells, it is advisable to represent them in the form of computer expert systems as databases and knowledge bases. In the field of interactions, triangular submatrices are distinguished, which consider the connections between individual characteristics of the same group, as well as rectangular submatrices of connections between different characteristics. Thus, each element of the matrix has a common cell with all other elements, which will contain information (Fig. 1).

When filling out the matrix, the significance of its characteristics is evaluated, taking into account the establishment of priorities. The most important characteristics (20 spatial and kinetic) were selected. The situations are identified when the connection between the elements of the matrix is absent, exists, important. The analysis of the matrix confirms the presence of a large number of controlled connections. Out of 780 cells related to urban planning activities, there are 172 interaction fields of connections. Other connections should be coordinated with other areas of activity. The possibilities of urban influence on the development prospects of the settlement system through 82 connections are the widest. They are manifested through the functional structure, natural

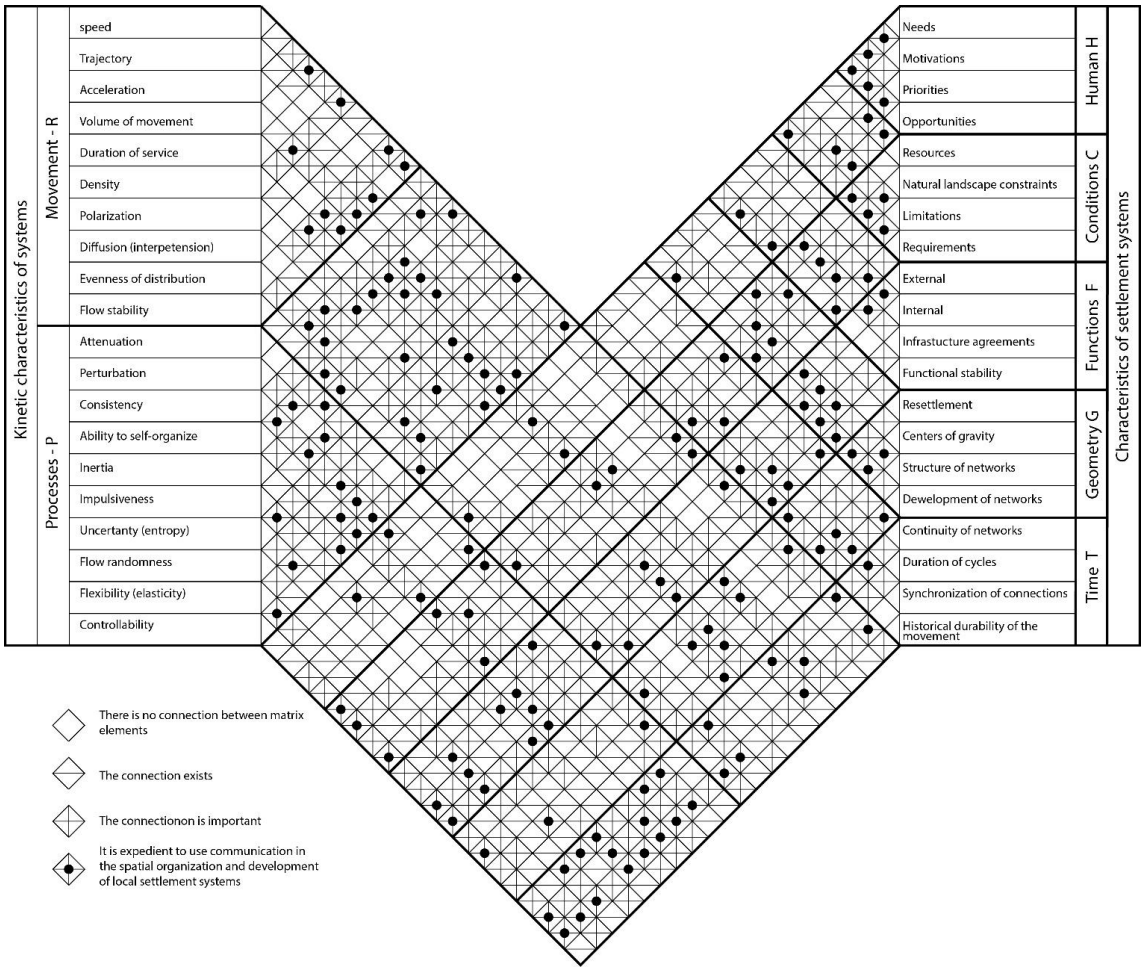

Fig. 1. Matrix of relationships of spatial and kinetic characteristics in local settlement systems. Factors influencing spatial organization and development [created by authors]

and landscape properties, technologies, living conditions, and management of space, but above all through communications. The role of aesthetic characteristics and traditions in the processes should also be emphasized. Contradictions also arise between the characteristics of individual dimensions. All managed connections, as well as those that are appropriate to use in the justification of decisions, should be reflected in the purposes of urban planning activities.

From the analysis of the matrix of connections, a number of important tasks arise for the implementation of the kinetic approach in agglomeration design. The package of such "typical" tasks is formed taking into account the interactions of spatial and kinetic characteristics. Thus, regarding the function of ensuring the connectivity of the system, it is necessary to take into account 28 characteristics.

The laws of classical mechanics (kinetics and dynamism) are experimentally confirmed, and their rethinking and use for the analysis and modeling of movements (people, substances, energy, information) in settlement systems are appropriate and correct. Kinetics can be expressed as dependence on a group of variables that are established from a matrix of relationships and have a strong and manageable relationship as a function of these factors.

The level of movement organization is assessed by an integral indicator of movement efficiency, which includes indicators of usefulness, economy, environmental friendliness, and safety. Increasing the efficiency of movements in settlement systems requires consideration of the entire array of characteristics of five-dimensional space and interactions of all dimensions that form spatial movements. An integral criterion for assessing kinetics in urbanized systems is the socio-ecological-economic efficiency of movements, which can be used to determine logistically advantageous or disadvantageous movements. In a general form, the integral evaluation of efficiency can be written as a dependence:

$$Э = f(K, N, C, H, G, T)$$

where Э is the social-ecological-economic efficiency of movements; K – useful results of movements; N – total negative consequences of displacement; C – expenditure of resources (including time) to obtain a result; H – characteristics of the human dimension, in particular the number of people participating in

the process and using it, the quality of relocation services; G is a geometric dimension, for example, the area occupied by the system; T – time (duration) of the effect of the result, time spent.

We propose to consider the spatial efficiency of movements in space as a relative indicator, where the numerator reflects the potential usefulness, the aggregate costs of resources, and the negative consequences of movements in the system, and the denominator reflects the characteristics of the human, geometric and temporal dimensions of space. It can be modified to

$$P_{\varepsilon} = \frac{K_к - (N_b + N_p + N_e)}{H \cdot G \cdot T}, \quad (2)$$

where P_ε is the spatial efficiency index of movements; K_k – total potential useful results of movements in the system in energy units; N_b – useful losses from various movements; N_p – loss of resources; N_e – negative consequences for ecology.

After simple transformations, we get the formula for the movement efficiency index:

$$P_{\varepsilon} = P_{max} \cdot [1 - f(B)], \quad (3)$$

where P_ε and P_{max} are, respectively, the actual and the maximum possible movement efficiency index; $f(B)$ is a function of space and movement disorder.

The movement efficiency index has urban planning significance. Its analysis makes it possible to identify existing trends in spatial processes and contradictions in the organization of space and communication systems and to justify directions for their optimization and integrated development. The performance index is an integral criterion that includes social, environmental, economic and aesthetic characteristics of solutions. A multi-criteria choice is required. Preference is given to the option for which the value of one of the criteria is preferable to the equivalence of the others.

Lviv local resettlement system: analysis of connections and movements and assessment of the kinetics

The local settlement system of the city is divided into three options (Fig. 2): the territory within a radius of 30 km from the city (a); the territory within the proposed second ring road; the territory within the limits of Lviv city territorial community (b). Statistical materials and data from geo-information systems and sociological analysis (interviews and surveys conducted in public transport by student experts on various directions of suburban movements) were used. The system of indicators and characteristics of the analysis and assessment of the local resettlement system of Lviv was divided into groups:

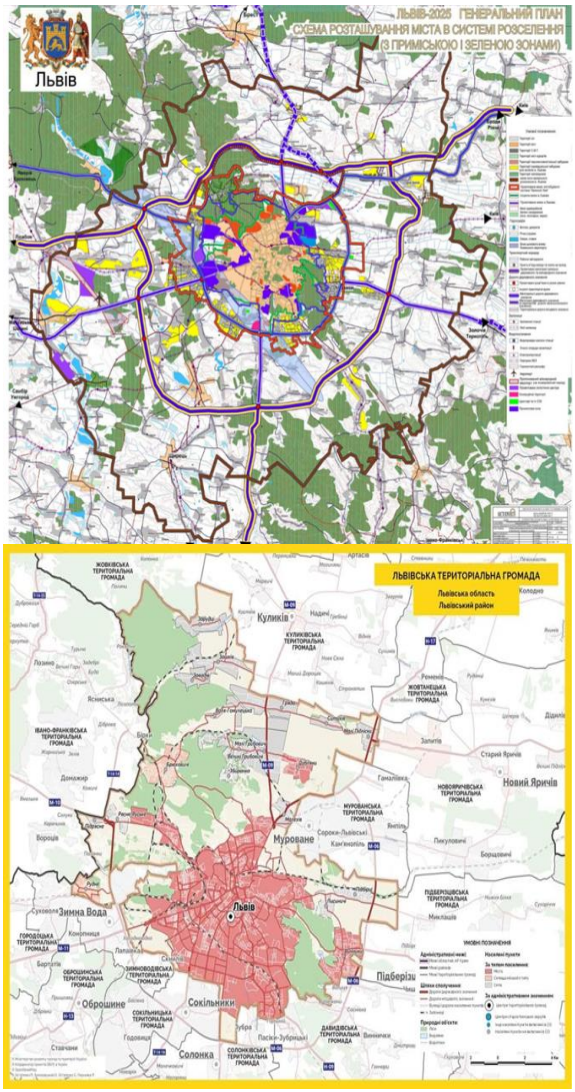

Fig. 2. Schemes of Lviv urban territorial community (a) and Lviv suburban zone (b) [created by authors]

1. The characteristics of the city center include the number and structure of residents; economic potential (employment prospects and the number of jobs); development of social and engineering infrastructure (water supply, food supply, energy supply); state and dynamics of the real estate market [17]. The main attention was paid to the city's transport network and engineering and transport problems.

Lviv is the largest multifunctional city in the western regions of Ukraine with an 800-year history, a large industrial center, and a transport hub in the past. The area of the city community is 315 square km, the population is 783,065 people, and the density is 2481.19 people/sq km. In the field of the city's transport system, there was a redistribution of freight and passenger transport in favor of road transport, and the demand for electric transport increased. The level of motorization has increased

from 100 to 300 units over the past 30 years per 1000 people.

Ten important directions converge in Lviv, and the centralization of transport communications is observed within the immediate environment. Within the city center, people move: 25 % by car; 24 % – by bus and on foot; 22 % – by electric transport; 4 % – by bicycles (22 %), 1% – by taxi, scooters, scooters, etc. The high density and historical value of buildings in the central part do not allow the reconstruction of streets with the expansion of carriageways.

The complex topography of the area significantly affects the choice of routes and the speed and safety of traffic. The location of the historical part of the city in the Lviv basin creates problems with the development of underground urbanism, including underground high-speed tram. Contradictions arise between the functional characteristics of the city space and the complex transport system. The functional structure of the city has developed historically and has a mosaic nature of interweaving zones of different functional content.

The Plan of Sustainable Urban Mobility of Lviv [19] has been developed to solve the problems of moving people, increasing network capacity, normalizing traffic, and moving around the city. However, it does not outline a systematic approach to solve key issues – public transport in the suburban area is underdeveloped, inefficient, and uncomfortable, and the city is "choking" from traffic jams. Lviv has entered the stage of functional "drying up". It is a phenomenon that has engulfed the once efficient city.

2. The characteristics of suburban areas include settlement system (location of settlements and their density), urban settlement, characteristics of the population (share of the urban population in these areas, ratio of the population of the suburban area to the city-center, employment and structure of employment, socio-demographic situation); economic development of the suburban area (structure of economic systems); the quality of the environment (the difference in the ecological state between the city center and the surroundings).

The suburban area of Lviv is almost 3 thousand square km (13 % of the regional territory), and the population is about 1.2 million people (approximately 45 % of the population of Lviv region, taking into account the population of the regional center). The spatial structure of the suburban zone of the city (Fig. 2b) is characterized by a variety of natural and landscape conditions, a high population density, a concentration of production, engineering and transport infrastructure, and the dynamism of economic and social processes taking place here.

One of the features of this territory is its location on the Main European Watershed, which divides the territory almost in half. Separate natural areas with a complex configuration are distinguished within the zone. They are the geomorphological area of Lviv Roztochchi, Davydivska hriada, and Hologora; the Lviv Plateau stands out from the south, and the Hryadove Pobuzhzhia, which is divided by the Poltva River and its tributaries, from the north.

The system of settlement in the suburban territory is characterized by unevenness: in the western direction within the borders of Zhovkva and Yavoriv districts, the farm system has been preserved; in connection with the construction of a military training ground in this area after the Second World War, the natural process of settlement formation was interrupted, it has not stabilized to this day.

The settlement network of the suburban zone of Lviv is characterized by different population sizes; quantitative predominance in the settlement structure of small and medium-sized settlements (from 5 to 10 thousand people), which mostly perform agricultural and recreational functions. It is also characterized by the absence of urban-type settlements in the settlement network of the rural administrative environment and intensive development of pendulum migration of the population.

3. Developed connections between the central city and suburban territories include transport accessibility of the central city (network and transport system development), distance from the center and accessibility to peripheral communities, economic relations between the central city and the surrounding territories (integration of the labor market, agricultural enterprises and land to provide the population with products), the share of workers in the center and suburban areas, functional connection, continuity of construction, the prevalence of urban lifestyle, the cohesion of territorial communities.

In conditions of depopulation and a decrease in the number and quality of functions (tourism is preserved, the IT sector is developed, the "fabric" is growing – residential construction as a static component) the kinetic structure degrades. The analysis of the relationship between the characteristics of space and indicators of kinetics in urbanized systems indicates the growing need to use multi-criteria methods in justification and decision-making.

The kinetics model makes it possible to evaluate the whole set of factors that ensure movement in space. A detailed analysis was carried out regarding the processes of: a) movement of people; b) functioning of life support engineering networks; c) the logistics system of providing products and goods.

a) analysis of population movement

Spatial and statistical parameters of pendulum migration can be traced on the example of Pustomyt, where 2/3 of the population of working age commutes to Lviv for work and study every day; the increased dynamics of the annual rate of growth of the population, which is due to the development of migration processes, primarily from rural areas [11]. Most settlements in the suburban zone are characterized by the development of post-suburbanization processes (construction of modern residential blocks, employment of the population in the tertiary sector, in particular in trade and the field of household services, the development of new means of communication, which provides the opportunity to work remotely, etc.). In quantitative terms, the volume of load on Lviv, which creates transit traffic flows, averages 348,000 residents.

The average volume of city traffic generated by the city's residents per day is more than 2 million trips by various types of transport, and tourists added more than 35,000 trips in peacetime. The most popular places of entry into the city are railway stations (46% of the total) and car roads (36%). Half of the total volume of human traffic is created by residents living in a 15-km zone around Lviv (more than 76,000 residents every day), as well as from settlements that are 4-10 km from the city (25% of the total volume, or more than 38,000 people). The most intense traffic was recorded at the exit point from the villages of Malekhiv and Murovane (4 thousand people) and through Horodotska (3.8), Stryiska (3.5), Lychakivska (3.3) streets (Fig. 3).

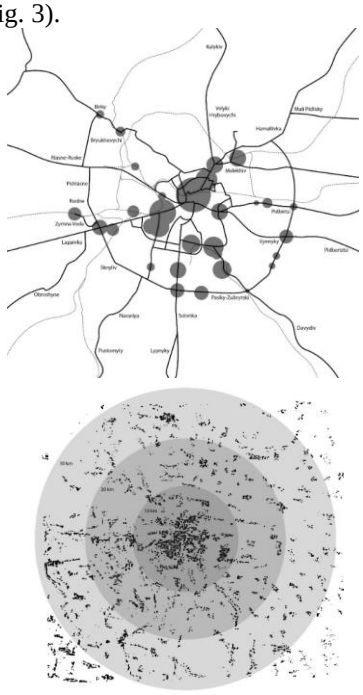

Fig. 3. Centers of active movement of people and scheme of public transport routes [created by authors]

According to the authors, slowing down the development of the transport network and public transport systems in the suburban area is due to the slowing down of suburbanization processes, which are connected with the increase in the cost of land in the city center. This factor reduces its influence with the creation of the Lviv City Territorial Community (2016) and the annexation of adjacent territories to the city. It was assumed that the development of off-street public transport would free up more space for other types of movement and the development of transport infrastructure.

b) the analysis of engineering systems of city sustainability

The water supply system in Lviv was gravity-fed for a long time and included water intakes, reservoirs and a water supply network. Today, Lviv's water supply is carried out exclusively from underground sources (18 group water intakes and 1 gallery), located at a distance of 20 to 80 km from the city. The explored reserves, provided they are effectively developed, are sufficient for the normal water supply of the city for the next 50 years. The city uses 45–50% of explored underground water reserves (280–300 thousand m3 of water per day; approximately 200 l/day (with the estimated capacity of water intake facilities of 452 thousand m3/day) per inhabitant). Due to the lack of demand, the Verkhnyobuzk water intake at a depth of 200 m is not used (available water reserves of 90,000 m3 per day). Thanks to the implemented zoning of the city water supply network and the creation of 11 hydraulically independent water supply zones instead of four, along with other actions (Project "Water Supply and Sewerage of the City of Lviv", 2008), the problem of water supply was solved (in 2002, 20% of the city residents used water around the clock; in 2009 – 89%; now – 100%). Water is supplied to the city by 581 km long main water pipelines. A complex and technologically important element of the system is the urban distribution network, the length of which is 800 km with only large-diameter pipes (100–900 mm).

The wastewater disposal system consists of 605 km of sewer networks (in 1938, the length of the city sewer system was 163 km). The city's domestic, industrial and storm drains runoff through the completely closed collector of the Poltva River (until the middle of the 19th century, together with numerous streams, flowed freely through the streets) enters the treatment facilities with a design capacity of 490,000 m3/day (consisting of two technological lines), where their mechanical and full biological cleaning is carried out. Since the natural and landscape conditions of Lviv cause frequent and large floods, the main river of the city could not cope, the problem was extremely acute:

c) the analysis of the logistics system of providing products (food security) and industrial goods to city residents

The city processes, receives, and sends hundreds of thousands of cargoes every day. Lviv is supplied with products and industrial goods, as a rule, from warehouses and within individual divisions. Companies in this field are improving the logistics system for competitiveness in the market. The companies "Logistic Park Lviv" and "Karpaty-Logistik", Devik, which are among the largest warehouse complexes in Western Ukraine, have new modern office and warehouse complexes and access roads to highways. The city is at the initial stage of creating logistics hubs. A universal warehouse and sorting complex "Postal and Logistics Center" (the area of 26,000 square meters), a new "Epicenter" in Sokilnyky (240,000 square meters), a logistics center in Pasiky-Zubrytskyi (a project of the Ukrainian company Regno, which is engaged in the import of various food products into Ukraine with the total area of the territory is more than 8 hectares), and logistics centers in the area of St. Horodotska, Taras Shevchenko, and Yaroslav the Wise are in the perspective of construction. The movement of resources and goods is linked to the location of storage, transportation, and sales centers and has a decisive influence on the movement in the system.

We evaluated the kinetics and the processes of movements against the background of the general processes of Ukraine in wartime conditions. Strengths and chances are highlighted:

- world support for Ukraine in the war with Russia;
- the integration of critical infrastructure into the EU common market;
- expansion of opportunities to attract funds from international structures for the reconstruction of critical infrastructure;
- modernization of national documents of the spatial development of territories according to EU standards;
- activation of technological development, improvement of access to modern technologies, creation of a new structure of the economy;
- strengthening Ukraine's position on the world market as a food supplier.
- Weaknesses and threats for Ukraine, the region, and the local system of resettlement of Lviv:
- the destruction of industry and critical infrastructure;
- a drop in real GDP, a decrease in the living standard of residents;
- mass migration abroad, demographic crisis, growth of unemployment among people of working age;
- problems of the agricultural sector, ineffective land policy;
- difficulty with logistics (blockage of ports, destruction of transport infrastructure);
- unfinished reforms (decentralization, judicial, tax, etc.).
- According to the kinetic model of "movement - space" relations, the following points are recorded in relation to the local settlement system of Lviv:
- relocation of production facilities. Lviv and the region became the main ones in the relocation of technological companies (before the war, the city was the third after Kyiv and Kharkiv in the IT sector - 30,000 specialists worked here; now the number has increased to 100,000 people);
- attempts to create a new structure of the economy and development of industrial parks and industrial clusters;
- development of transport and logistics infrastructure (completion of the north-western part of the ring road of Lviv, formation of transport and logistics hubs on the border with the EU, narrow railway to Lviv);
- formation of a temporary resettlement system of forced migrants. According to estimates, more than 500,000 forced migrants have moved to Lviv Oblast, 200,000 to 250,000 of whom intend to stay here. More than 200,000 people from Lviv Oblast are "wage earners" who have gone abroad for a long time;
- increased attention to the viability of systems and security (production, storage, logistics, processing, realization of energy resources and food, cooperation, control over resources);
- unsystematic territorial policy and reservation of plots for the development of infrastructural systems of the region.

Based on a well-founded kinetic model and analysis of movement processes in the system, the initial requirements for the spatial organization of the agglomeration are determined under the conditions of increasing the movement efficiency index.

Justification of solutions for the spatial organization and development of the "Great Lviv" agglomeration based on kinetic requirements

Spatial organization as a means of ensuring the harmonious integrity and development of the system involves defining the components of space and arranging the connections between dimensions: people (social) – functions (economic and operational) – conditions (natural and legal environment) – time (cultural and historical) – geometry (layout and composition). Its main purpose is the formation of spatial order, effective
exploitation, and development of territories, protection of the natural and historical environment, stimulation of socio-economic processes, coordination, and complex solution of coordination, investment, control, and security tasks. A special role belongs to the issues of managing territories and resources, as well as increasing the "connectivity" of space.

Based on this understanding of the tasks of spatial organization and development of the local settlement system, the requirements for the "Great Lviv" agglomeration are formed. We interpret the city and the suburban zone as a kinetic system, accordingly, it is advisable to focus development on increasing the efficiency of processes, connections, and relations (connections and movements):

1) *coordination of local and general processes*: general and local goals, integral and partial criteria for assessing its achievement, determination of priorities (resource and time), the hierarchy of functions and "powers". Special attention needs to be paid to optimization of boundaries, assessment of resources and networks, coordination of interactions;

2) *equalization of spatial accessibility conditions* is associated with the reform and development of the street network of the central city, public transport systems, terms and sources of financing, regulation of traffic, etc. Important evaluation criteria are operational losses, energy efficiency, capital intensity, safety, environmental friendliness and comfort;

3) *minimization of unproductive movements* by reforming and harmonizing spatial characteristics (social, functional, natural-landscape, geometric, historical) with a priority on new technologies and information systems;

4) *development of inclusive and elimination of extractive systems* that inhibit development. Property rights, in particular to land, should be rationalized as conditions for stimulating infrastructure development, avoiding mistakes in construction and land speculation;

5) *regulation of movements at different levels* means wide use of scientific achievements, primarily in the field of urban planning, sociology, economics, and informatics, development of new management technologies and their implementation in practice, involvement of scientists in analytical work, increasing the level of provision of the apparatus with decision-making support systems based on modern methodology and informatization tools, compliance with the principles of publicity and transparency in activities.

The development of local regional settlement systems and agglomeration planning is aimed at revealing the uniqueness of space, each subsystem of which has its own geographic, economic, social, geometric and historical specifics. The kinetic model is most consistent with the policy of integrated development and is associated with the revitalization of degraded space and an increase in the efficient use of non-renewable resources (primarily land). It is aimed at strengthening the identity of cities and districts, which should be accompanied by increasing the dynamism and competitiveness of the entire space of the settlement system, the effective formation of a systemic combination of the central city with the surroundings, which become more attractive, capable of meeting growing needs at the expense of common resources, the creation of conditions for coordination of processes and needs of balanced territorial development of the entire region in conditions of dynamic processes and phenomena.

The substantiation of the priority directions in development will take place on the way of clarifying dichotomies, in particular, the strengthening of existing ones, such as the development of new structural connections in the territory, "integration - isolation" of nature protection, and economic objects, the choice of economic forms of using the spatial potential of the region, etc. Thus, in dichotomies:

1. of urbanization – deurbanization should be focused on the development and return to life of small towns and towns, the spread of urban lifestyles;
2. a mono-functional - poly-functional structure should focus on expanding the functions of both the central city and the suburban zone, increasing the functional flexibility of the system;
3. of concentration – deconcentration of economic activity, deconcentralization is more beneficial, which is more consistent with the spatial structure and historical traditions of management in the allocated territories;
4. monocentric – the polycentric structure of the supporting centers indicates the need for support and development of settlements of the environment and the creation of new growth centers;
5. closeness – the openness of the location system, traditions and processes in the region confirm the need to effectively expand the openness of the system to the external environment, strengthen existing and build new structural ties.

The answers to dichotomies allow us to substantiate the principles of spatial organization and development of local settlement systems according to the requirements of kinetics: unity, dynamization of space, and consistency of dimensions. The unity of the spatial organization is connected with the transit function of the agglomeration. Throughout its history, Lviv was not characterized by high indicators of these processes, which were influenced by the specifics of natural resources, political and economic conditions. These principles receive active development in new political and socio-economic conditions, form the demand for the dynamization of space, and the coordinated development of transport, engineering, and information communications. Macro characteristics, which are substantiated when outlining the prospects for effective interaction of the city and its suburban zone, include functionality, communication efficiency, compactness, the dynamism of space, and the development of the structure.

The model of spatial organization and development of the "Great Lviv" agglomeration which was formed on the basis of kinetics provides: 1) strengthening the

integrity of the entire spatial system (settlement, and the functional and planning structure of the territory, including the integration of recreational, agrarian functions and etc.); 2) increasing the dispersion of the settlement structure by supporting the development of small settlement elements through a change in functions; 3) strengthening the multifactorial differentiation of the functional structure of territorial elements according to efficiency criteria, as well as taking into account the specifics of natural and landscape conditions, the nature of settlement and management, historical and cultural features; 4) redistribution of transportation in favor of effective public transport systems and creation of conditions for alternative communications, development of transport infrastructure in the system, formation of transfer stations from private to public transport, increasing the number of slow-moving and pedestrian streets, allocation of public transport lanes, etc.; 5) increasing the multifunctionality of the space (when the working place is near the place of residence); 6) allocation of communication spaces of local settlement systems as a separate administrative-territorial layer of the region. There are various options for "collecting" communication systems into the spatial structure of territorial systems, such as by means of spatial planning and urban design, the creation of metropolitan areas that cover the central city and surrounding communities (with the mandatory provision of powers to solve tasks and perform metropolitan functions).

Conclusions

1. The properties of urbanized systems are characterized, and the special role of dynamism and kinetics in the development of the settlement system and agglomeration planning is emphasized. The central factor in all types of movements in urbanized systems is the events and processes that take place.

2. The nature of movements and kinetics as an all-encompassing phenomenon is characterized. The analysis of fundamental and applied theories of movement indicates the usefulness of the laws of classical mechanics and the principles of thermodynamics, the general theory of systems, and engineering systems for substantiating the kinetic model of the development of urbanized systems, ordering indicators, and criteria for evaluating their kinetics.

3. The kinetic model of the development of local settlement systems is presented in the form of a multidimensional matrix (which includes 20 indicators that characterize space and 20 characteristics of movements) and contains the information about the five-dimensional model of urban planning space "man – functions – conditions – geometry – time". The matrix makes it possible to analyze both individual elements of space and their interactions (780 combinations) in order to evaluate the state of space according to the criteria of kinetics and to substantiate the ways of urbanized system development on the basis of kinetics.

4. The methodological value of the kinetic model is confirmed, which reveals wide possibilities for the analysis and assessment of various spatial situations, as well as the coordination and synthesis of spatial organization and development of local settlement systems. The requirements for modeling the spatial development of agglomerations are substantiated (they range from the selection and structuring of information to the search for ways and means of using modeling results).

5. The provisions of the kinetic model were applied for the analysis, evaluation, and justification of the concept of spatial organization and development of the local settlement system "Great Lviv". The prospects of Lviv as an agglomeration in the system of connections and relations with the environment are revealed. The requirements for development and proposals to optimize movements within the agglomeration are substantiated. It is necessary to focus on the search for solutions that reveal the uniqueness of the city and its surrounding space.

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Kopsavilkums. Pētījumā tiek pētītas vietējo norēķinu sistēmu kinētiskās sastāvdaļas ar realizētiem procesiem, kas saistīti ar cilvēku, materiālu, enerģijas, informācijas u.c. kustību. Tiek piedāvāts lokālo norēķinu sistēmu organizācijas un kontrolētas attīstības kinētiskais modelis, kas balstās uz zināšanām par kustību teorijām un ar tām saistītām telpas īpašībām un sniedz iespēju organizēt savienojumus starp tās apakšsistēmām un dažādu sfēru elementiem.