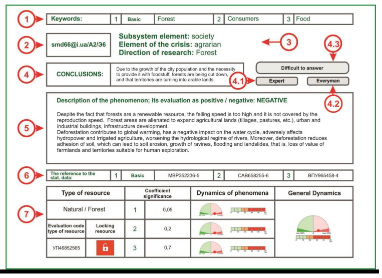

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INFORMATION MODEL OF ANALYSIS OF CITY AS A COMPLEX DYNAMIC SYSTEM

INFORMACYJNY MODEL ANALIZY MIASTA JAKO KOMPLEKSOWY SYSTEM DYNAMICZNY

Serhii Danylov
PhD Arch.

Kharkov National University of Building and Architecture
Faculty of Civil Engineering and Architecture
Department of Urban Planning

ABSTRACT

The article describes the newly developed innovative methods that allow monitoring the dynamic processes occurring in the city and evaluating it as an open, complex and dynamic system. Based on these methods, an information accumulative interactive model of analysis of functioning and development of the city was developed. The developed model is the basis for a cognitive research model that allows: identifying the necessary and sufficient number of indicators of sustainability, crises and possible disasters in the city; forming step-by-step strategies for rehabilitation of urban areas; interactively analyzing the reaction of the urban environment to planned adjustments to optimize its vital processes.

Key words: city, system, crisis, cluster, model, sustainability, catastrophe.

PURPOSE

Developing a model complex for monitoring and managing dynamic processes of functioning and development of the city that is adapted for the needs of the architectural practice.

1. ARTICULATION OF ISSUE

Modern city has reached such a level of complexity that the old methods of managing the vital processes in many cases prove to be ineffective. Considering the city as an open dynamic system, one can assert that each urban system, subsystem or an element has its own dynamics. Changing under pressure of external and internal factors, they face the constraints imposed by adjacent systems and put pressure on them. As a result, contradictions between the basic interests of various systems and elements emerge. These contradictions can be improved by considered regulation but they can be exacerbated by errors and miscalculations of designers and managers.

Thanks to compromises in the conflicts of interests, the city can exist and develop. If new boundaries of compromises are established the system acquires stability, otherwise it enters into a state of crisis. In the case when the crisis is aggravated, there is a threat of a catastrophe. Thus, the city's system exists in the conditions of constant dynamic changes. Identifying such critical boundaries and developing methods for overcoming them are the main tasks of research of the city as a dynamic self-developing system. The result should be a conception of the mechanisms for preserving the city's stability. The effectiveness of such forecasting is determined by the cost of errors, which can result in empty cities and billions of losses.

An attempt to find solutions to crisis situations empirically in such a highly complex system as a modern city is foredoomed to failure. With the current apparent and implicit relationships between almost all aspects of the city‘s activity, most local solutions for adjusting one crisis can have unforeseen consequences. A new tool is needed to analyze the current state of the city's system and its elements in terms of stability or crisis and forecast their future possible states.

Considering architecture as a part of the dynamic process of the city‘s activity, a researcher faces a lot of different problems [9]. The famous triad of Vitruvius: firmitas (strength), utilitas (usability) and venustas (beauty) combined with the social and environmental aspects of architecture’s existence, create a complex of problems that is extremely difficult to resolve without new scientific and technological innovations.

The prerequisites for development of the proposed methods include a certain level achieved in computational technologies, which allows interactive processing of large amounts of data.

2. METHODS OF RESEARCH

In the study, the information model of the city is considered in two main aspects: A. Collection, classification and storage of information; B. Analysis and information management.

A. Collection, classification and storage of information

Collection and storage of information. Methods of developing an information accumulative model of the city.

To collect information about the city as a system methods for multi-disciplinary interaction are developed in the study. One of its aspects is integration of unrelated databases. Particular attention is paid to combining the statistical data held by different urban services into a single model. In this case, it is practically proposed to attempt to create a digital interactive database of the city and the processes in it.

An important fact is that the process of creating interactive city models affected almost all aspects of city life:

- Social modeling [7], [8], [3]
- Modeling of a city as a complex spatial system (for example, SIMPOP2) [1];
- An integrated approach to the creation of a model simulating the dynamics and growth of cities [13].
- Logistic modeling [2]

The following directions of creating interactive city models are developed in architecture:

- Studying visual comfort of the urban environment [4].
- Spatial modeling as a basis for further analysis of the urban environment [9].
- Generative modeling as a way of optimizing the work with the master plan [6]
- Data classification.

The existing problem is unique due to the fact that almost every city on the municipal level has a sufficiently complete description of almost all processes and phenomena in it. The information flows are not connected into a single systematized model, which does not allow predicting the response of the urban system to external and internal changes with a high degree of reliability.

The system analysis was chosen as one of the research methods. Applying this method allows us to classify the city as an open dynamic system with a great number of elements, a complex character of the links between these elements, the complexity of the functions performed by the system and risk of losing the equilibrium state.

The previous article [5] pointed out that for the needs of architectural practice methods of classification of architectural information flows on the basis of cluster and typological analysis were developed.

System dynamics methods are used as an environment for studying complex systems that can be changing over time, as well as in the conditions of structural adjustment and dynamic changes in the external environment. In this area of research, the achievements of Forrester and his school were used as a model [10].

As a prototype for developing an intuitive interface for direct and reverse dialogue with large arrays of data, the approaches of the Any Logic and Data Mining programs were used.

B. Analysis and information management. Methods of developing a cognitive research model of the city

Cognitive research model of the city is a superstructure over an information accumulative model. Without the possibility of carrying out analytical research, the collecting and structuring information becomes meaningless. In urban services, the data necessary for management has already been processed and structured.

At the current stage of the research, methods for establishing parametric links between data packets concerning elements of the city system are being developed. The methods of graphical and spreadsheet parameterization are being adapted for this. Presumably, the works of Molodtsov D. [11] can provide the mathematical apparatus. Taking into account the complexity of the problem, this aspect is considered as a working hypothesis, which requires a multidisciplinary study.

To create a cognitive research model of the city methods of identifying cognitive gaps in the city conceptions of representatives of different paradigms are used. For this purpose, a matrix of combining cognitive maps was developed, which is also a matrix for identifying complexes problems of the city as a dynamic system.

3. RESULTS OF THE STUDY

3.1 Information accumulative model of analysis of functioning and development of the city as an open dynamic system

As a result of investigation of contradictions of the city as a dynamic system, it was defined that it is necessary to create a model complex designed for its analysis. This means that an innovative system of work with arrays of data about the city is needed. It will help to streamline information flows, involve in the scientific search dozens and hundreds of scientists from different spheres and organize a scientific testing ground for the results obtained on virtual models in real time. In fact, this is a precedent when it is necessary to merge urban planning, architecture as well as philosophy, sociology, ecology, innovative technologies, statistics, and hundreds of paradigms in order to obtain a model describing both the current state of the system and predicting its state in the near future and to the horizon of predictions.

An information accumulative model of analysis of functioning and development of the city as an open dynamic system has been developed. By monitoring the dynamic processes that make the basis of the city functioning, this model allows us to identify the hierarchy of these processes by assessing the degree of their impact on the city. As a result, we obtain a tool that can track and manage complex information flows, analyze them and combine data according to predefined parameters. The feedback has been established, and thanks to that this tool is a means of predicting and testing the changes that are introduced to the city.

In the frame of managing large arrays of architectural and construction information, synthesis of methods for cluster analysis and classification of objects of the urban environment was developed. Classification is in fact a kind of hierarchical tree whose structure itself defines the direction and area of clustering the objects. This approach is defined by the need to consider an architectural object not only as a typological unit – hard landscaping / building / block / neighborhood / district / city, but also as an object comprising the processes unrelated to architectural and construction activities and participating in functioning of the city as a system.

In our case, clustering of objects located in some particular analyzed area is assumed. Clustering can be as detailed as level of tasks set before the architect requires. Potentially, even the smallest objects, such as garbage bins and bicycle parking lots, can be included in the analysis. Each of such objects has its own, unique set of statistical data.

A hierarchical structure of architectural clusters is developed. It is based on the territorial principle - object / quarter / district / administrative area / city. Besides, for representatives of the related fields of knowledge, the concept of a technological, social and ecological cluster, also according to the territorial principle, was introduced.

In fact, each cluster can be considered as a kind of passport of the object where all the information available to analysis is recorded. Naturally, even at the level of an apartment building, the flow of information can create such dense information chaos that any sense will be lost. Therefore, currently an intuitive interface for direct and feedback dialogue with digital arrays of data is being developed.

Each cluster is presented as a complex of material and information components (patterns) that regulate its life activity. The cluster is presented as a continuum of patterns that determine the dynamics of the cluster's life activity taking into account all its processes. The principle of splitting information about the architectural cluster into an array of specialized patterns is developed. The developed model of pattern compilation into specialized clusters, which are characteristic for other non-architectural areas of knowledge, allows providing vertical and horizontal links between all hierarchical elements of the urban system.

Each pattern or its fragment can be a part of other clusters related to other paradigms. So the part of the pattern "Residents of the house" can belong to the clusters "Pensioners", "Voters", "The Sick", "Children", "Reservists", etc., forming the subsystem "City Community". Solar panels, cogeneration units, heat pumps, solar collectors and other innovations can constitute "Power of the district" cluster from the subsystem "Technosphere", etc. Thus, almost all city patterns being a part of a certain set of clusters through the dynamic processes of their life activity in a certain way connect all urban elements between each other. Thanks to this approach, a system for establishing parametric links of all clusters of the city through the dynamic processes of the patterns linking them to each other, was developed.

Based on the logic of the architectural tasks, the lower hierarchical level of clustering is defined - the object typological cluster. At this level, each object of the urban environment is taken as a separate cluster and described in the most accessible fullness of its inherent information. The cluster is presented as a sum of patterns grouped by the attributes for assigning them to one of the three subsystems of the city: the ecosphere, the technosphere or the society. Thus, each object can be evaluated from the standpoint of its environmental impact and it can be described as a physical object and its social component and significance can be determined. Each of the presented subsystems of the cluster is divided into a material and information level of vital activity.

At the material level, the physical state of the object created on the basis of its statistical history, is described. Since the created model is interactive and each of its elements is described digitally, each cluster pattern can have its own pop-up menu with the necessary information attached to it.

At the information level, the possible influence of the ideal component of the each subsystem on a cluster as a whole is evaluated. Such components may include: laws, statutes, ideology, religious and ideological imperatives of the population, etc. Naturally, it is almost impossible to adequately assess some ideal components but in fact the degree of influence of statutes on the object and the urban system can be taken into account.

As working prototypes of the software shell of this model, the methods of establishing parametric links of Any Logic program were used. This allowed to interactive assessment of the internal and external changes occurring in the city system. The general idea of constructing a direct and reverse dialogue with large arrays of data embedded in this program was used to develop an intuitive interface of the model. The logic of Data Mining program for data intellectual analysis was used to reveal hidden regularities and regularities in arrays of heterogeneous multidimensional data.

For each of the patterns that make up a cluster, on the base of the obtained statistical data, the dynamics of the processes of its vital activity is evaluated using system dynamics methods. These methods allow to take into account the fundamental interrelations between the elements of the system (clusters), fluctuations in the dynamics of its development and also to determine how the vital processes of each cluster affect the dynamics of development of other elements of the system. To combine different in their structure and nature data packets, the method of their analysis according to the "basic rate of growth" was chosen. As a result, an assessment of the cluster's state (stability, crisis or pre-catastrophic state) is made from the sum of the vectors of the patterns' dynamics evaluation.

All processed statistical data are collected in a single information array with linked parameters, which becomes a model of structured information that actually represents a digital model of the city. Thus, with digital package of statistical data, we have an opportunity to construct in automatic mode a dynamic model of temporal development of the processes that occur with the considered cluster. Even static objects that do not have any complex structure, through their life processes are inevitably connected with other objects of the analyzed territory (for example, a park bench can be a hardscape element for improving comfort of the urban environment and an object that increases employment).

Thus, the developed information accumulative model allows:

- to capture and take into account an unlimited number of information blocks reflecting the diversity of factors in the functioning and development of the city. To fix the links of its key elements. To accumulate statistical data and dynamic maps of as many processes as possible in the city;
- by monitoring the dynamic processes taking place in the city to evaluate it as an open, complex, dynamic system, all elements of which are interrelated and mutually influenced;
- to simulate the behavior of the city's system under conditions of ever-changing data, to analyze direct and reverse links between the main elements of the system, to identify and diagnose negative scenarios of its development;
- thanks to the developed methods of establishing parametric links between the dynamic processes in the society, the technosphere and the ecosphere as constituent parts of the city, to define the hierarchy of these processes by assessing the power of their influence on the city; this allows determining the urgency and importance of decisions, it allows predicting, and thus avoiding a number of system errors that can critically affect the situation in the city.

3.2. A cognitive research model for analysis of functioning and development of the city as an open dynamic system

To correlate specialized languages and cognitive maps when developing complex methods for analyzing problems of a city as a dynamic system, a cognitive research model was developed. This model is a superstructure and a tool for managing large data arrays contained in an information accumulative model that had been built earlier.

The model is built on the principles of multidisciplinary interaction of representatives of different fields of knowledge and allows combining different languages describing the problem in a single research space. To minimize gaps between cognitive maps of perception of the problems of city functioning and development, methods for detecting cognitive distortions are used.

The proposed model is universal for designers, specialists in sanitary engineering, ecologists, builders, philosophers, sociologists and other specialists, whose scientific interests in any way relate to the analysis of the functioning and development of the city's system. The principles developed in the study combine multiple paradigms reflecting various aspects of city's functioning and help to obtain a clearly assessed and comprehensible model that allows defining those measures that can bring on positive changes in the entire urban system without losing positive qualities accumulated by it, and thus maintaining stability.

In effect, building the model sets a precedent when it is necessary to merge data of urban planning, architecture as well as philosophy, sociology, ecology, innovative technologies, statistics, and hundreds of paradigms in order to obtain a model describing both the current state of the system and predicting state of the system in the near future, to the horizon of predictions.

In the process of developing methods of multidisciplinary interactions, the problem of cognitive distortions on the border areas of knowledge about architecture and the city is revealed. The most obvious areas of such distortions and gaps in cognitive conceptions are areas of innovative technologies that combine several paradigms from different areas of scientific knowledge. This phenomenon is most noticeable when working with the principles of sustainable development, a smart city, an environmentally friendly city and a number of other concepts of innovative trends in the city's development.

The hierarchy of the model consists of the model itself, which is a verbally and statistically described core of the problem with assessment of its vital activity dynamics. At a lower level there are professionally compiled groups of data describing a specialized view of the problem. The groups of data are presented in the form of tables where horizontally the analyzed elements of the city subsystem are indicated: the ecosphere, the technosphere and the society (Fig.1). Crises from paradigm "Sustainable development": energy, economic, social, demographic, raw material, agrarian and cultural, are located vertically (at the first working stage of the model development).

CRISIS	PRINCEPS SD	Socium Element: Consumers A	Economy Element: Consumers B	Ecology Element: Consumers C
DEMOGRAPHIC	1			
AGRICULTURAL	2			
ECOLOGICAL	3			
ENERGY	4			
ECONOMIC	5			
CULTURAL	6			
SOCIAL	7			

Fig. 1. Table of identification of professional / philistine assessment of the considered problem. Source: Developed by the author

In the cells at the intersection of columns and lines, an "Event" formed as an information case is identified (Fig.2). It consists of the following graphs:

1) The code for identifying the "Event" consisting of: the code of the table, the code of the case and the code of the respondent;
2) The set of topics of the "Events", which include: a) Name of the crisis (energy, economic, social and so on); b) Name of the element of the subsystem (the ecosphere, the technosphere and the society); c) Key topic, which is the topic of the "Core of the problem", therefore it is present in all the events of the model and gives the general direction of the study. For example, energy efficiency; garbage; branding of the city; retail; biodiversity and so on.
3) Annotation of the event identified and described by a respondent in no particular format on the basis of three given topics.

   Example: keyword "Forest", element of "the society" subsystem: "Consumers", an element of "Agrarian" crisis: "Food Products". 1: Due to the population growth, forests are cut down to clear land for growing crops to supply people with necessary food. Here the phenomenon of deforestation corresponds to key word "Forest"; the need to expand arable land corresponds to “Agrarian” crisis ; the need for food corresponds to subsystem "Society".

4) An event can be evaluated positively or negatively. If the assessment is negative, the respondent, on the basis of the identified keywords, is asked to describe the same event as a positive one. For example: Option 1: Expanding the arable land area due to cutting down forests allows solving the problem of stable supplying the population with food products. Option 2: The growth of the society’s demand for organic food products stimulates development of such an innovative direction in architecture as urban agricultural enterprises.

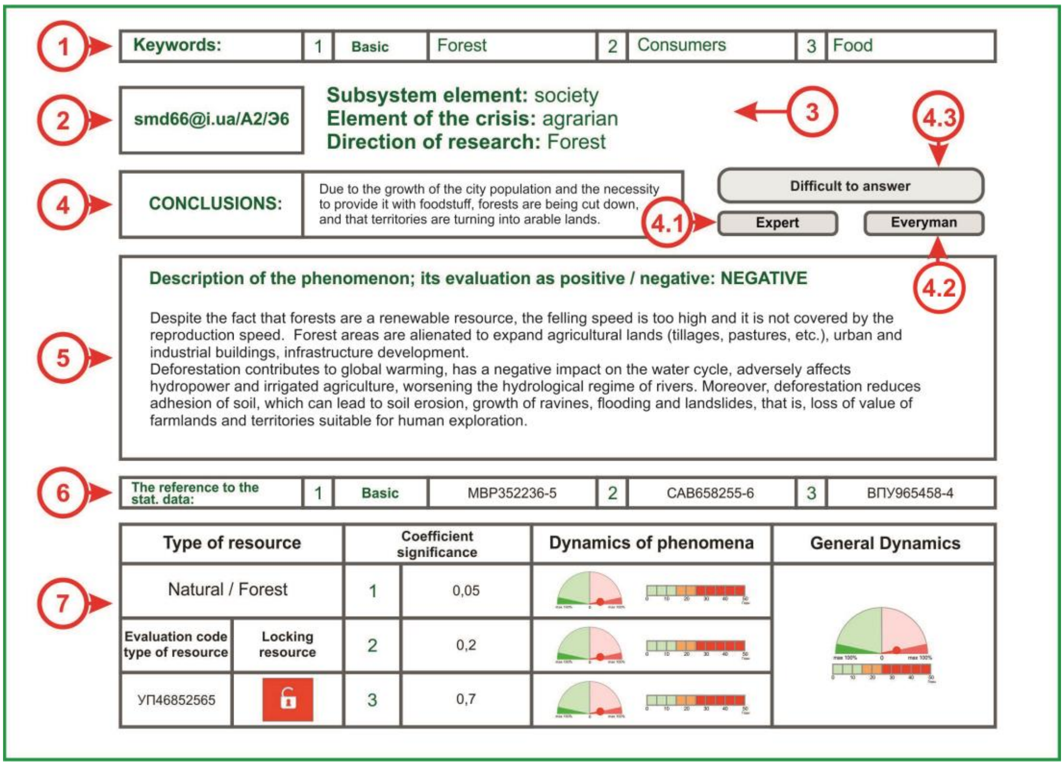

Fig.2. Case of "Event" description. Source: Developed by the author

This procedure is for identifying the necessary indicators, which in the future will be transformed into indicators of stability of crises and catastrophes. The signs of such indicators are: a) abrupt modification of the main values; b) major changes in values as a result of small administrative impacts; c) difficult return to the values of the previous state; d) different reactions to the influence of the same factors under the fixed conditions; e) an increase in frequency of fluctuations of their characteristics.

5) Based on the statistical data taken from the information accumulative model, the dynamic characteristics of each phenomenon described by a keyword (deforestation, arable land, etc.) are calculated;

6) One of the phenomena described by a keyword is defined as the backbone factor of "Event" (for example, "Deforestation"), which is fixed in the corresponding column;

7) Assessment of the resource which the event refers to - human, natural or economic

one. This will determine the dynamics of changes in resource consumption in reaction to adjustments of some aspects of the urban system;

8) The coefficient of event significance. It is identical to the similar coefficient from the information accumulative model and allows determining the degree of impact of the event on the system;
9) Estimation of the dynamics of the event is defined as the sum of the dynamics vectors from Section 5 taking into account the coefficient of significance.

As a result, each participant of the process on the basis of statistical data and professional conceptions describes his series of events that create his professional cognitive map. This map demonstrates a spectrum of specialized aspects of considering a particular city problem. Free format of interpretation of the events is necessary for determining the field of specialized conceptions of the considered problem that the representatives of various fields of knowledge have. Verbal description of the event will allow combining the cognitive maps of the problem conceptions by transforming the professional description language into a popular presentation form accessible to a broad spectrum of users.

For example, today it is obvious that cities have lost their resource independence, and, consequently, immunity to a number of crises: water, energy, food, raw materials, etc. In addition, increase in labor productivity and robot automation in industries generates a new phenomenon - change of the city-forming factors of many megacities of the world and so on. In this context, representatives of various fields of knowledge sometimes highlight the diametrically opposed aspects of the problem.

Architecture: in overpopulated countries such as Japan, China, South Korea, etc., the conception of vertical urban development is popular. In the countries with less density, the conception of uniform settling of people throughout the country in small eco-cities is developing.

Ecology. One of the stable trends of this professional field is desire to limit the number of internal combustion engines in cities. At present, for a number of economic and social reasons, China's attempts to follow this direction have not been successful in the established eco-cities.

Example of solid household waste. In terms of considering the problem of solid domestic waste the area of intersection of the environmental crisis and the "Ideology" section from the "Society" category is especially complicated. Resolution of the environmental and other crises is 60% dependent on developing the ecological consciousness of mankind and only 40% on the technologies. These data are very approximate, but they express our opinion on the problem.

In architectural terms, Ariel Sharon Park near Jerusalem where the latest achievements of innovative technologies are introduced, demonstrates how much a smart, cautious approach to the problem of garbage can improve the ecological tension of this issue.

The next example is the intersection of the "Society" subsystem with the keyword "Health" and the “Demography” with key word "Age." It is well-known that the more active the people of retirement age in the country, the more stable its economy is. Active and healthy lifestyle implies a special approach to the formation of the urban environment.

Combination of the key words "Socialization" and "Emigration" in one case revealed a complex of deep basic contradictions in city organization concerning human migration. This topic is analyzed in detail in the third section. The problems that can potentially be transformed into a pre-catastrophic state were identified. They are the following:

"Society" subsystem:

In this case, the following indicators of the area under consideration begin to play a key role: assessment of the composition and quantity of the migrating human resources, the ratio of the rate of emigration and the speed of assimilation, and growth of social tension. In architecture, migration gain implies increasing fractalization of the city and marginalization of the least prosperous areas, which leads to security upgrade to ensure safety of its residents. Oddly enough, the migration outflow of the population leads to the similar results - the emigration of the wealthiest inhabitants leads to marginalization of the districts. Pruitt-Igoe complex can be an example of marginalization of a residential area, where a number of social, technology-related and environmental crises have taken place there due to adoption of the segregation law that led to a catastrophe. As a result, it was decided to demolish it.

"Technosphere" subsystem

For developed countries, migration gain means a revival of the economy, an increase in production and consumption. When assessing the potential of the event the industrial and energy potential of the region, the availability and shortage of vital resources play an important role. For architecture, at the initial stage of the problem development migration gain means a construction boom, which will favorably affect the professional sphere, and routinely an "economic bubble" will appear in the real estate market.

"Ecosphere" subsystem

In the situation of population growth, the demographic pressure on the environment increases. In this case the following indicators become important: the coefficient of biological footprint of mankind, biological capacity of the region, the development of the city's infrastructure for collection and utilization of waste products and availability of water resources. All these data allow us to determine the environmental consequences of exceeding the critical number of the city's population. For architecture, this means the development of innovations aimed for example at rehabilitation of ecologically depressed city districts. They include: green standards, energy efficiency, bioclimatic zonation and so on.

The whole of the recorded and statistically described events constitute a complex of interconnected problems of the city. Establishing the parametric links between "events" allows the following actions:

1) Parametric link between of the indicator of the problem complex and the system status indicator allows to artificially improve or worsen the state of the complex of events, thus causing a corresponding response of all elements of the city system as a whole. Clusters and events as elements of the system that had the sharpest reaction to such "swinging" should be considered as the least stable ones.
2) These elements are grouped together, which should be regarded as indicators of stability, crises and catastrophes.
3) Each of the indicators of elements is connected to the specific coordinates of the urban environment and therefore can be displayed interactively on the GIS city map.
4) An analysis of the principles for distribution of indicators across the city allows assessing the characteristics of its sustainability.
5) The resource type in the cases of column 7 allows identifying the relation of the types of the resources needed to correct the problem areas of the urban system.
6) The model provides for the possibility of blocking a particular type of resource (human, natural, economic) from a group of cases or indicators that were investigated and evaluated as "stable". If the type of resource is blocked, all fluctuations of dynamics changes in the city subsystems will not be displayed on blocked cases or indicators. As a result, it becomes possible to search for improvements in qualities of the urban system without losing its stability.
7) The developed model provides for the possibility of verbal description of the identified sustainability / crisis / catastrophe indicators. The model enables to combine them into a group that has aggregate dynamics and to introduce these indicators into a cumulative information model. Such operation will make it possible to determine in

the interface of the model a separate group of the agents most sensitive to changes, which will allow adequate assessment of the threats to the stability of the city as a dynamic system.

The developed cognitive research model allows:

- monitoring the development of the city as a dynamic system, making forecasts of its development within the horizon of predictions;
- identifying necessary and sufficient number of indicators of stability, crises and possible disasters of the city and predicting systemic risks potentially capable of critical impact on the processes of development and functioning of the city;
- determining the necessary and sufficient number of these indicators, the impact on which will help restore balance in the city system;
- analyzing interactively the respond of the urban environment to the planned adjustments to optimize its vital activity;
- defining urgency and importance of measures to correct the problems of the city development, defining those measures that can bring on positive changes in the entire urban system without losing positive qualities accumulated by it, that is keeping its stability;
- the structure of the model allows generating new research directions of the city as a system defining the vector and structure of the research.

6. CONCLUSIONS

The developed model complex is relevant for developing the strategic programs of city development when determining the architectural and town-planning policies. The complex nature of the research and applying the latest information technologies allows taking into account the goals of both individual components of the city and the system as a whole and helps to find a negotiated, compromise solution for its optimal functioning and development. Modeling makes it possible to evaluate the consequences of the taken decisions on computer models, and thus avoid possible adverse consequences of ill-conceived managerial decisions.

The sources of effective implementation of the developed methods are: achieving sustainable development of the city as a result of the adoption of the best management decisions; increasing the adequacy of the information analyzed; optimization of forecast of city development; improving the quality and objectivity of the generated strategic decisions and choosing the most rational of them; reducing the number of critical errors from irrational management decisions.

Currently, the author of the article together with the masters of the department carries out approbation of the developed method in one of the Kharkiv districts. The district has unique nature and landscapes: a pine forest, a lake with an area of 0,8 km2, the Udy river, and meadows. Besides, a historical hillfort of the VIII century AD is located nearby, 7,5 km away from the city center, 4,2 km of them by a four-lane highway. The district is also unique in terms of existing problems: A) 12 plants, the sanitary zones of which cover the existing bedroom suburb; B) abandoned filtration fields of Dikanevsky sewage treatment plants (1,1 km2), contaminated chemically and biologically; C) not developed infrastructure of the district; E) a lake, which appeared over the last 50 years as a result of sand mining; F) high (in comparison with the prosperous districts of the city) marginality level of the population.

Such set of problems has become an excellent testing ground for the methods under development. As a part of ongoing research, each projected element is considered as a cluster that has unique qualities and affects the overall environmental, social and economic situation of the area. Aim: to create a model of a self-sufficient district that has a positive effect on the social and environmental situation in the city.

BIBLIOGRAPHY

[1] Bretagnolle A., Pumain E., Pumain D. (2006) From theory to modelling: urban systems as complex systems Cybergeo: European Journal of Geography URL: http://journals.openedition.org/cybergeo/2420; DOI: 10.4000/cybergeo.2420.

[2] Crainic Tg, Ricciardi N. Storchi G. (2009) Models for Evaluating and Planning City Logistics Systems. Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation. (CIRRELT), 53 p.

[3] Crooks, A.T. Constructing and Implementing an Agent-Based Model of Residential Segregation through Vector GIS [Text] / A.T. Crooks. – Centre for Advanced Spatial Analysis (University College London): Working Paper 133. – 2008. – 42 p.

[4] Czyńska, K. Wykorzystanie wirtualnego modelu miasta do badania zasięgu widoczności panoram. Przestrzeń i Forma. 2009, nr 12; 103-114 pp.

[5] Danylov, S. Methods of cluster analysis in the investigation of the city as an open dynamic system // PRZESTRZEŃ I FORMA. NR 32/2017. SPACE & FORM NO 32/2017. czasopismo naukowe Polskiej Akademii Nauk DOI: 10.21005/pif. 32_2017. B-02. P. 117-126. e-ISSN 2391-7725 | ISSN 1895-3247.

[6] Koenig R. Generating urban structures: a method for urban planning supported by multi-agent systems and cellular automata. Przestrzeń i Forma. 2011, nr 16; 353-376 pp.

[7] Makarov, V.L. Printsipyi monitoringa kachestva zhizni na osnove agent-orientirovannyih modeley (Principles of monitoring the life quality on the basis of agent-based models) [Text] / V.L. Makarov, V.V. Okrepilov // Vestnik Rossiyskoy akademii nauk. – 2016. – # 8. – S. 711-718.

[8] Makarov, V.L. Sotsialnoe modelirovanie – novyiy kompyuternyiy proryiv (agent-orientirovannyie modeli) (Social modeling - a new computer breakthrough (agent-based models) [Tekst] / V.L. Makarov, A.R. Bahtizin. – M: Ekonomika, 2013. – 295 c.

[9] Meadows Donella H., Randers Jorgen, Meadows Dennis L. (2004) The Limits to Growth: The 30-year Update. Chelsea Green Publishing Co. 338 p. ISBN: 9781931498586.

[10] Michael J. Radzicki and Robert A. Taylor (2008). "Origin of System Dynamics: Jay W. Forrester and the History of System Dynamics". In: U.S. Department of Energy's Introduction to System Dynamics. Retrieved on 23 October 2008

[11] Molodtsov D.A., "The structure of benign sets", Fuzzy systems and soft computations, 12: 1 (2017), 5-18.

[12] Rubinowicz P. Generation of citygml lod1 city models using bdot10k and lidar data. Przestrzeń i Forma. 2017, nr 31; 61-74 pp.

[13] White Roger, Guy Engelen, Inge Uljee (2015) Modeling Cities and Regions as Complex Systems: From Theory to Planning Applications. The MIT Press, Cambridge, Massachusetts. 344 pp., ISBN 9780-262029568.

AUTHOR'S NOTE

Serhii Danylov – PhD. arch. Kharkov National University of Building and Architecture, Department Urban Planning. Research directions: innovative methods of analysis, modeling and design of the architectural environment.

Contact | Kontakt: smd66@i.ua