NEWTONIAN ANALOG METHOD IN MODELING THE EFFECTS OF URBAN PLANNING SELF-ORGANIZATION

ANALOGOWA METODA NEWTONA W MODELOWANIU EFEKTÓW SAMOORGANIZACJI PLANOWANIA PRZESTRZENNEGO

Anna Hoblyk
Ph.D., Associate Professor

Kyiv National University of Construction and Architecture
City Development Department

STRESZCZENIE

Artykuł rozpatruje osobliwości związane z aplikacją analogowej metody Newtona w matematycznym modelowaniu efektu samoorganizacji w planowaniu przestrzennym. Prezentuje również analizę kompleksu produkcyjno-usługowego „Rynok Pivdennyy" („Rynek Południowy") w Lwowie bazującą na technicznej analogii.

Słowa kluczowe: system planowania przestrzennego, metoda analogowa Newtona, potencjał czasoprzestrzenny obszaru, lampa Lava.

ABSTRACT

The article deals with the peculiarities of application of Newtonian analog method in the problems of mathematical modeling of the urban planning project self-organization effect. It also presents analysis of the commercial-production complex 'Rynok Pivdennyy' ('Southern Market') development in the city of Lviv based on its technical analog.

Key words: urban planning system, Newtonian analog method, territory space-time organization potential, Lava lamp.

1. INTRODUCTION

A city by its nature is a complicated dynamic nonlinear urban planning system consisting of a multitude elements and innumerable nonlinear relationships between them. The structure of the city exists as changeable in time, and at each time period is simultaneously complete and simultaneously open for further development. Due to the non-linearity of the direct and inverse relationships between the system elements occurrence of various phenomena and processes hard to predict and such that produce an effect on further scenario of the system development is typical for a city.

One of present day problems of urban planning is the problem of the urban planning systems management effectiveness enhancement under the conditions of their complexity and limited resources. Under some conditions the said problem may grow into the problem of total loss of control of the urban planning system development. The key contradiction that lies at the base of this problem is, that the city management administration, governing institutions at a certain stage of development of the city can not carry on management of the highly dynamic processes of the urban planning systems development, and the city residents, city communities do not want such an ineffective administration. The problem of management of the urban planning systems development is closely connected with a range of other problems. Cities, as the urban planning system from the standpoint of management, appear to be the exceptionally complex open systems with their typical effects of non-linearity and self-organization. With the development of cities both, complexity their of structure and that of the urban planning projects grows due to the increasing number of relationships between the projects with their characteristic nonlinearity. A complete loss of control over the dynamic urban planning system occurring at the time of its transition from the “orderly” state into the “chaotic” state takes place in the event of total degradation of the prevailing social values accumulated by the authorities of local self-government bodies. Resolving the problem of envisaging development of urban planning systems in the perspective requires elaboration of adequate numerical models and the new, more productive computing means that correspond to the urban planning systems complexity.

Thus, of exceptional topicality at present stage is the problem of elaboration of the new mathematical models describing on the quantitative level synergetic effects that appear in the urban planning systems with the purpose of improving effectiveness of the development of urban planning systems management.

2. THEORETICAL PREREQUISITES FOR STUDY OF THE PROBLEM

Despite the fact, that from the standpoint of the present day scientific literature presents a well-established concept of the material world as such whose fundamental properties are the 'self-organization' and 'non-linearity' [3], the problem of elaboration of quantitative methods of analysis of self-organization effects and non-linearity in the very urban planning systems remains to stay in the state that is far from being completed. Urban planning systems are regarded as hypercomplex systems and at certain stages of their development as highly dynamic systems. To each point of the urban space can be mapped territory space-time organization potential [9]. Such potential effects can also describe a set of non-linear scenarios of the urban planning system development.

It would be appropriate to note, that the idea of self-organization or synergetics was conceived in the classical science of the 18-19 centuries. These were cosmological hypothesis of Kant-Laplace, C. Darwin’s evolution theory, Maxwell-Boltzmann theory of behavior of thermodynamic systems. However, it was only in the 70’s of the 20th century that the critical mass of the collected theoretical material and practical experience was achieved to be transformed into the fundamental studies of open non-equilibrium systems, analysis and description of the mechanisms and regularities of their development. The principal provisions of the synergetics theory have been presented in the works of H. Haken,

G. Nicolis, I. Prigozhin [7, 11] in the 70's of the 20th century. The term "synergetics" was introduced in scientific use by H. Haken. The works of V. Vernadskiy, B. Belousov, A. Zhabotinsky, A, Rudenko, Yu. Klimantovich, A. Kolmogorov [3,10] played an important role in the establishment of the self-organization theory. Modern science moves forward towards theoretical generalization and modeling most complicated anthropogenic systems capable of self-development and self-organization, to which urban planning systems belong as well. Analysis of the latest studies on the subject of the present article [1,2,4,8,13,14] has shown, that the problem of mathematical modeling of the processes and effects of self-organization in the urban planning systems at the present stage of development of the theory of urban planning remains to be unconsidered by the specialists urban planners.

That is why the objective of this work is the task to apply creatively Newtonian analog method for description of self-organization processes in the cities and the task to elaborate in the perspective new mathematical models describing the effects and processes of self-organization in urban planning systems.

3. THE IDEA OF COMPLEX SYSTEMS SELF-ORGANIZATION IN THE URBAN PLANNING THEORY

It is through the prism of the self-organization theory that the problems of rapid growth and spatial transformation of the urban structures are considered more and more often in recent years despite the fact that the very term 'self-organization' contains a certain contradiction. Indeed, undeniable is the fact described in the work [5], that 'The emergence and development of the city has been since the times immemorial a well-planned process that was carried out by the authorities. This is the way the ancient Greek colonies and later Roman cities were founded. In the same manner barons or bishops founded cities in the European Middle Ages. This is exactly the way the cities were founded in Russia both, before and after Peter the Great'. Thus, the theory of the planned determined development of cities and settlements is set off against the synergetics theory of urban planning processes development. However, representatives of H. Haken school [4, 7, 8], the founder of synergetics theory, believe that under the present day conditions self-organization in no way suggests absence of planning in the city. Self-organization in the cities is understood as several parallel planning processes with participation, for example, of separate individuals, families, companies, representatives of the authorities, who in this case are regarded as 'town planners' of a certain scale. Thus, self-organization in the city reflects a cooperative structurization and organization of a large number of plans on the individual scale.

4. I. NEWTONIAN ANALOG METHOD

The process of self-organization in social-economic systems and its materialization in the spatial-planning structure of the city can be suitably demonstrated on the example of formation and development of the shopping malls or trade markets (enterprises) areas in the cities.

In the early 1990's a greater part of the cities of present day Ukraine experienced the 'clinical death' as stoppage of enterprises and total unemployment forced city dwellers to look for new resources for their survival. This is how the first spontaneous 'flea markets' appeared in the cities, predominantly in the stadiums or in other vacant areas, and numerous trips of the 'shuttle traders', former engineers, teachers, blue collar workers began for the commodities to Poland, Rumania, Turkey. In the following twenty years one could observe transformation of the spontaneous flea markets in Ukraine into more or less spatially organized and comfortable for the buyers and traders trade malls.

Commercial-Production Complex (CPC) 'Rynok Pivdennyy' ('Southern Market') (Fig. 1,2) in the city of Lviv serves in this work as the object of the study, and peculiarities of the process of self-organization of CPC “Rynok Pivdennyy” territory serve as the subject of the study.

We shall note that operation of the largest in the Western Ukraine CPC 'Rynok Pivdennyy' was started in 1996 by P. I. Pysarchuk. Owing to his talent and remarkable organizational skills personnel of CPC 'Rynok Pivdennyy' has taken a unique for the territory of Ukraine course on the principles of the urban planning system self-organization. 14 trade complexes function today on the territory of about ten hectares that include about two thousand trade outlets, supermarkets, a food market, hotel, church, medical center, sport complex and fitness-center, notary, banking and mail services, restaurants and numerous cafes. CPC 'Rynok Pivdennyy' provides jobs for almost 17 thousand residents of Lviv.

Taking into consideration that CPC 'Rynok Pivdennyy' is a unique phenomenon of implementation of the fruitful idea of its founders based on the principles of self-organization this urban planning project was selected for modeling processes of urban planning systems self-organization in this work.

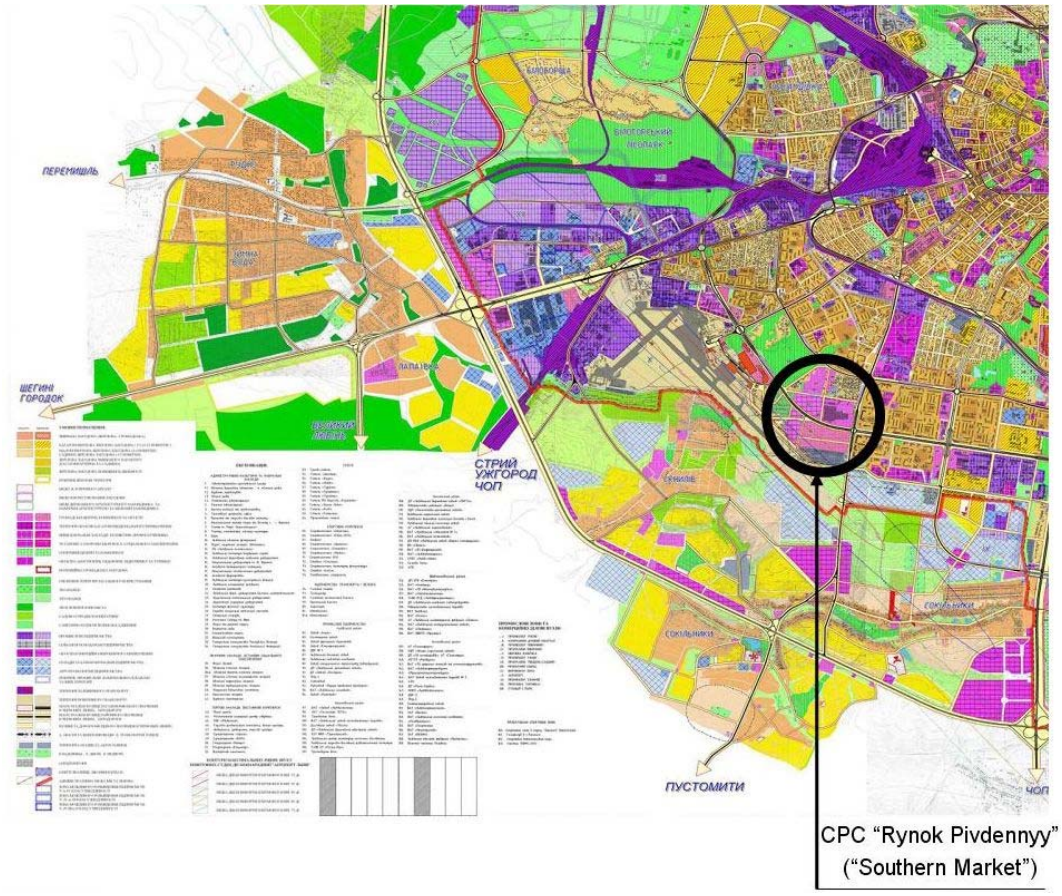

Fig. 1. Lviv masterplan, 2025 (fragment). Source: http://www.tcp.com.ua

Fig. 2. Commercial-Production Complex 'Rynok Pivdennyy'. Source: Google Earth

As a remote analog of the process of CPC 'Rynok Pivdennyy' self-organization is the principle of Lava lamp operation (Fig. 3). The lamp was designed in the 1960's by the Briton Edward Craven Walker.

The analog method itself for modeling the process of CPC 'Rynok Pivdennyy' self-organization was borrowed from I. Newton, who published his rules of reasoning in his work [16]. These rules presented below have proved remarkably enduring till our day:

'*First rule* - admit no more causes of natural things than are both true and sufficient to explain their appearances;

Second rule - to the same natural effect, assign the same causes;

Third rule - qualities of bodies, which are found to belong to all bodies within experiments, are to be esteemed universal;

Fourth rule - propositions collected from observation of phenomena should be viewed as accurate or very nearly true until contradicted by other phenomena'.

This analog method was extensively applied by the founder of 'Cybernetics' [15] N. Wiener for modeling technical systems by analogy with animate nature, in particular, for the problems of the study of systems characterized by self-organization.

Let us note, that it was the second rule of I. Newton (1726) that allowed Charles Coulomb to discover the 'Coulomb Law (1785),' and Andre-Marie Ampere – the 'Ampere Law

(1820)' [6]. The analog for the formulation of these laws was the Newtonian law of gravitation. These fundamental discoveries in physics are the indisputable argument in favor of the correctness of application of I. Newton's analog method for the problems of modeling self-organization processes in urban planning systems.

5. LAVA LAMP AS AN ANALOG OF CPC «PIVDENNYY MARKET» SELF-ORGANIZATION AND THE PRINCIPLE OF ITS OPERATION

Let us consider the processes of self-organization in the Lava lamp for further development of the mathematical model of elementary self-organization processes in urban planning systems on the example of CPC "Rynok Pivdennyy".

The process of self-organization in Lava lamp – a decorative lamp that appears to be a translucent glass vessel (usually a cylinder) filled with translucent oil and semi-translucent paraffin and an incandescent light bulb underneath the vessel – is, as described in the description presented in the work [17], as follows. The incandescent lamp heats up and illuminates contents of the cylinder thus causing displacement of paraffin in oil. The effect is based on the fact, that at normal temperature paraffin is slightly heavier than oil (and drowns in it), and when slightly heated it becomes a little lighter and floats.

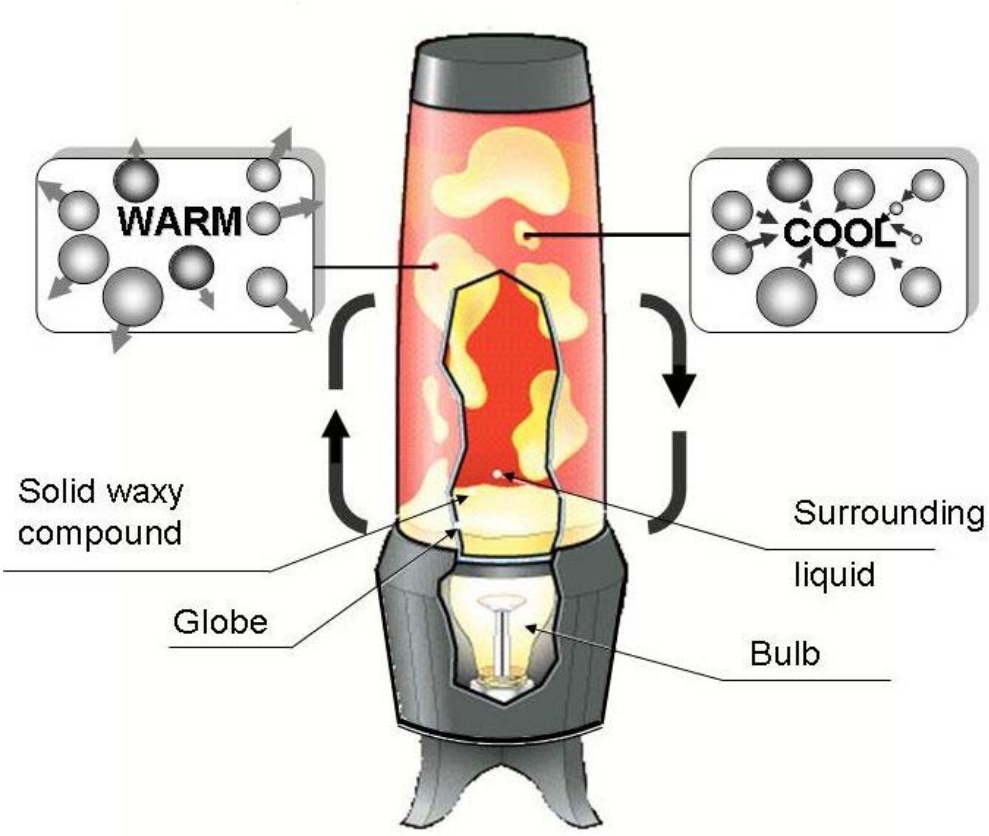

Fig. 3. Lava lamp. Source: http://home.howstuffworks.com/lava-lamp1.htm

We shall note that such description is insufficiently informative for detecting all the nuances of the process of self-organization in the Lava lamp that is based on the circulation of paraffin in oil in a closed contour of certain geometry. Such description does not present physical conditions ensuring reproduction of such process in the Lava lamp.

Therefore, a more detailed analysis of the process of functioning of such a decorative lamp permits to determine the following conditions necessary for occurrence of self-organization effect of the substance contained in the cylinder.

The Lava lamp (Fig. 3,4) consists of a translucent glass vessel, usually a round cylinder. The cylinder walls are not only translucent for the visible range of frequencies, but heat-conducting as well and for this reason can ensure temperature exchange of the internal decorative substance with the external air environment. That is, the first condition for the origin of self-organization process in the system is fulfilled – the system must be open for energy exchange with the external environment.

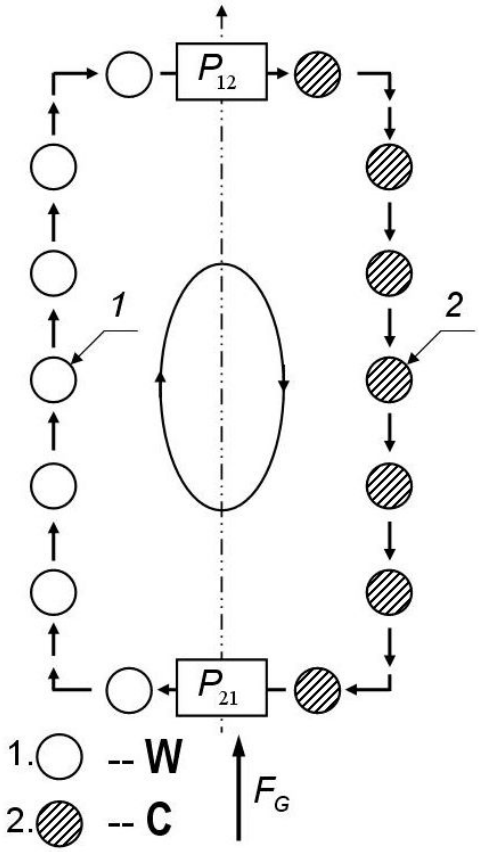

Fig.4. Principle of operation. Source:Hoblyk A.

The vessel contains working decorative mixture of the two components: translucent oil and translucent paraffin of different colors to create a decorative effect.

The oil and paraffin are chosen with special requirements to their specific gravity. Specific gravity of oil must be greater than specific gravity of paraffin in liquid state and smaller than specific gravity of paraffin in solid state. Optimally specific gravity of oil must be equal to the specific gravity of paraffin at the point of its transition from liquid into solid state. Fulfillment of this requirement ensures presence of the second condition for the occurrence of the self-organization process in the Lava lamp. The paraffin component must periodically transit from liquid into solid state and vice versa. Paraffin passes into solid state because of its cooling by the air environment in the upper end of the vessel and passes into liquid state in the area of the vessel bottom owing to the heat of the external source of energy produced by the incandescent lamp from electric current. Having passed into solid state and thus having increased its specific gravity paraffin falls to the bottom of the vessel and, having received another portion of heat energy from the incan-

descent lamp for transition into liquid state paraffin with the decreased specific gravity begins to rise to the upper end of the vessel, etc. Presence of the external source of energy (the incandescent lamp) transforming paraffin from liquid into solid state is the third necessary condition for the occurrence of self-organization in the Lava lamp.

The fourth condition for the occurrence of self-organization in the Lava lamp is presence of the gravitational field (gravitation field of the Earth). Lava lamp will not function in the state of weightlessness in the space orbit. Under the Earth conditions the Lava lamp must be installed so that the entire axis of the cylindrical vessel is aligned with the vector of the Earth gravitational force (gravitational field). This will ensure the process of heavy paraffin falling from the top to the bottom of the vessel.

The process of self-organization in the urban planning systems is shown in the generalized drawing of Fig. 4 that is an analog of the process of self-organization in the Lava lamp where:

$P_{2.1}$ – operator transforming substance from state '2' into state '1'.

$P_{1.2}$ – operator transforming substance from state '1' into state '2'.

FG – force of the gravitation potential.

To simplify the analysis let us consider the elementary process of self-organization in the CPC 'Rynok Pivdennyy' environment taking into account the mutual effects of other self-organization processes of different nature, complexity and character.

We shall examine the origin and development of the self-organization process in the trade channel by analogy with the process of self-organization in the Lava lamp. For this purpose we shall construct the 'Analogs table' (Table 1) of self-organization in the Lava lamp and self-organization of the elementary trade channel 'Lviv-Krakow' formed between the trade point in the internal market (Lviv, Ukraine) and the trade point in the external market (Krakow, Poland). We shall indicate such channel as 'Lviv-Krakow'.

Table 1. Analogues table

	Lava lamp	Trade channel «Lviv-Krakow»
1.	Glass lamp bulb filled with oil	Transport corridor
2	Melted paraffin wax (state 1)	Money equivalent of the goods at market prices in domestic market (Lviv, Ukraine) (state 1).
3	Paraffin wax in solid state (state 2)	Goods purchased at market prices in external market (Krakow, Poland) (state 2)
4	Operator $P_{2,1}$ (incandescent lamp), transforming paraffin from solid (2) into melted state (1).	Operator $P_{2,1}$ (seller), transforming goods (state 2) into money equivalent of the goods (state 1).
5	Operator $P_{1,2}$ (radiator), transforming paraffin from liquid state (1) into solid state (2).	Operator $P_{1,2}$ (wholesale seller), transforming money equivalent of the goods (state 1) into goods (state 2).
6	Gravitation potential	Potential of the territory space-time organization with relevant attractiveness of the goods for buyers.

Let us consider the process of self-organization in the trade channel 'Lviv-Krakow' as on the principle of Lava lamp operation taking into account analogies presented in Table 1.

1. The analog of the trade channel transport corridor 'Lviv-Krakow' where circulation 'money-commodity-money' is taking place is the glass vessel of the Lava lamp filled with oil;

2. The analog of the money equivalent of commodity at market prices in the internal market (Lviv, Ukraine) (state 1) is paraffin in liquid state (state 1);

3. The analog of commodity purchased at market prices in the external market (Krakow, Poland) (state 2) is paraffin in solid state (state 2);

4. The analog of Operator $P_{2,1}$ (seller), transforming commodity (state 2) into the money equivalent of commodity (state 1) is the incandescent lamp transforming paraffin from solid state (2) into liquid state (1);

5. The analog of Operator $P_{1.2}$ (wholesale buyer), transforming the money equivalent of commodity (state 1) into commodity (state 2) is the radiator transforming paraffin from liquid state (1) into solid state (2);

6. The analog of the territory space-time organization potential characterized by the 'attractiveness' of commodity for the buyers is the gravitation potential.

In case of absence of the attractiveness potential the trade channel 'Lviv-Krakow' shall not function. This means that there must be a demand for the goods delivered in our case from Krakow.

Now let us describe the process of self-organization in the trade channel.

By analogy to the Lava lamp the seller fulfills the function of the incandescent lamp transforming paraffin from solid state into liquid state, that is, exchanges commodity for money. The wholesale buyer performs the act of purchase in the trade channel, for example, purchasing in Krakow a new shipment of goods whose market price owing to the higher labor productivity in Krakow is considerably lower than the market price in Lviv. For this reason under the effect of the field of attractiveness potential to sell the goods in Lviv with a profit, the wholesale buyer by analogy with paraffin in solid state that falls to the bottom of the lamp, delivers the goods to the trade outlet in Lviv and this goes on in cycles.

The process of development of commodity circulation in the trade channel is reflected in the Lava lamp by modeling the process of paraffin circulation, whose weight increases with time and with simultaneous increase of the incandescent lamp capacity.

Increasing the bulk of commodity in the trade channel through profit intensity of the seller’s labor and the trade outlet attractiveness potential ensures development of the self-organization process in CPC “Rynok Pivdennyy”.

6. CONCLUSION

Improvement of the effectiveness of management of urban planning systems is not possible without the fundamental studies of the effects of self-organization in animate and inanimate nature, social-economic and urban planning systems.

The example of the commercial-production complex self-organization described in this work shows participation of the city residents on their level in the process of planning development of their city. The result of such self-organization today is stated in the Master Plan 2025 of Lviv: the territory of the described CPC “Rynok Pivdennyy” has been assigned the role of the community center in the southeastern part of Lviv.

Owing to the analog method of I. Newton it was possible to formalize in the first approximation the process of the trade object self-organization. The next stage of the work envisages elaboration of the mathematical model that would allow not only to describe the process of commodity circulation in the trade channel, but also the process

of development or materialization of money resources in the form of construction of urban development projects (trade complexes, engineering infrastructure, etc.) accumulated in the result of this 'trade channel'.

BIBLIOGRAPHY

[1] Allen P. *Cities and Regions as Self-organizing Systems: Models of Complexity*, Routledge, 1997.

[2] Barros J. City of Slums: self-organization across scales, in: *Working paper series, CASA University College London*, vol. 55, 2002.

[3] Chernogor L. *On the Nonlinearity In Nature and Science*, Kharkiv, Kharkiv V.N. Karazin National University, 2008.

[4] Daffertshofer A., Haken H., Portugali J. Self-organized settlements in: *Planning and Design: Environment and Planning*, vol. 28, 2001, 89 – 102 p.

[5] Glazychev V. *Urbanistika [Urban studies]*, Moscow, Evropa [Europe], 2008.

[6] Gliozzi M. *Storia della fisica*, Torino, 1965.

[7] Haken H. *Information and Self-Organization: A Macroscopic Approach to Complex Systems*, Springer, 2006.

[8] Haken H., Portugali J. A synergetic approach to the self-organization of cities and settlements, in: *Planning and Design: Environment and Planning*, vol. 22(1), 1995, 35 – 46 p.

[9] Hoblyk A. Optimization of the territory's spatial organization in a high risks zone, Manuscript, Thesis for the degree of PhD in specialty 05.23.20 – Town- and territorial planning, Kyiv, Kyiv National University of Construction and Architecture, 2006.

[10] Malineckiy G. Novy oblik nelineynoy dinamiki [The New aspect of nonlinear dynamics], w: *Priroda [Nature]*, nr 3, 2001, 3 – 12 s.

[11] Prigogine I. *The End of Certainty. Time, Chaos and the New Laws of Nature*, Simon and Schuster, 1997.

[12] Pugachova Ye., Solov'yenko K. *Samoorganizatsiya sotsialno-ekonomicheskich sistem [Self-organization of social – economic systems]*, Irkutsk, BGUEP, 2003.

[13] Tarasova L. *Gradostroitel'noe planirovanie i regulirovanie razvitiya krupnych gorodov s uchetom deystviya protsessov samoorganizatsii [Urban planning and regulation of development of large cities with taking into consideration the self-organization processes]*, Moscow, Moscow Architectural Institute, 2010.

[14] Timokhin V. *Harmoniynist evolyutsiynoyi dynamiky samoorhanizatsiyi mistobudivnykh system [Harmonicity of evolutionary dynamics of urban systems self-organization],* Kyiv, Kyiv National University of Construction and Architecture, 2004.

[15] Wiener N. *Cybernetics or control and communication in the animal and the machine*, New York 1961.

[16] Whitehead A., Russell B. *Principia mathematica 3 (2 ed.)*, Cambridge: Cambridge University Press, 1927.

[17] Warlamov A. Tayny volshebnoy lampy [Secrets of the magic lamp], w: *Kwant [Quantum],* nr. 7, 1986, 15 – 21 s.

AUTHOR'S NOTE

The author is an architect, urban planner, PhD. Associate professor of Lviv Polytechnic National University, Institute of Architecture, Department of Urban Planning. She is carrying out postdoctoral research at Kyiv National University of Construction and Architecture since 2012 year. Scientific interests are: urban development, mathematical and computer modeling of urban planning systems; spatial planning.

Kontak | Contact: a.hoblyk@gmail.com