Spatial-Temporal Dimensions and Principles of Sustainable Development of Ecological and City-Planning Systems

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Summary. This work showed results of the research of the methodological foundations for sustainable development of ecological and city-planning systems. This work clarified the applicability of the fundamental law of the sustainable development of open systems – the law of conservation of powers. This work established spatial and temporal dimensions of ecological and city-planning systems "population ↔ environment".

Key words: ecological and city-planning systems, sustainable development, environmental balance, demographic capacity, spatial-temporal dimensions.

INTRODUCTION

Since the beginning of human society, the civilization and development of natural processes are inextricably linked not only historically. These processes are dependent on each other developing by some laws. This understanding of the relationship of nature and mankind as complex systems that evolve on the base of common universal laws receives more and deeper understanding and lighting not only in the natural and social sciences [1, 2, 3, 4, 5], but also in city-planning ones [6, 7, 8, 9, 10].

MATERIALS AND METHODS

The purpose of the study is to determine the fundamental principles and spatial-temporal dimensions of sustainable development of ecological and city-planning systems. During the execution of work we used systematic approach, modeling and comparative analysis. As a basic method we have chosen analogy method, which is a tool for comparative analysis and is widely used in environmental studies.

STARTING POSITION

In the presentation of the modern science, the development of any system is, above all, changes of its state defined by a set of values of the main characteristics of the system [11, 12]. For city-planning system it is, above all, the size of the area of its territory, population, functional and planning structure, social engineering and transport infrastructure [7, 8, 9, 10, 11]. Development is a movement, without which nature cannot exist. At the global scale there is the acceleration of this movement, which is subject to the development of any system, including city-planning development [3, 11, 12, 13].

PURPOSE AND STAGES OF DEVELOPMENT OF ECOLOGICAL AND CITY-PLANNING SYSTEM

City-planning system, which originated as a temporary settlement of people in the "boundless" space, initially had no significant impact on the environment and its changes were barely noticeable. Gradually, the system grew in numbers, expanding geographically, got structurally complicated by functions and combined with other systems like it at the informational level. Today it is a highly complex ecological and city-planning system (ECPS) with excessive anthropogenic pressure on the environment and limited resources [11].

Ecological city-planning system as a set of "population ↔ environment" that creates a new quality, cannot be understood only by studying the properties and states of its components. This system cannot be understood without knowledge of the general laws of formation and development of the world around us.

The development of systems is based on the information programs of cooperation in space and time. "Living organisms, ecosystems, human relations, economic actors, cities are developing... Development is a irreversible, directed, regular change of system based on implementing of the internal mechanisms of self-organization... Self-organization is the process of organizing the internal structure and flow of matter, energy and information passing through a multidimensional system, which is provided with mechanisms of regulation of the system (feedback mechanisms)" [12, p.25].

The mechanisms and strength of self-organization and self-regulation are aimed at streamlining of ecological and city-planning system [9, 10, 11]. The above is subject to the desire to achieve the goal of a particular multi-cycle development of this system – the state of sustainability within a range of environmental (vibrational) balance [4, 5, 6, 11]. At the same time, the development is associated with the ability of the system to self-development – sustainable transformation and change. The self-development cannot be without self-organization and self-regulation, ensuring sustainability conditions – conditions under which the system is able to accumulate the energy required for its further transformation [12, p.26].

At the initial stage of formation and development of city-planning systems, the livelihood of people in the settlements is more governed by the laws of the family relationships. Later these settlements turned into city settlements. Their livelihood was governed by the laws of cooperation – the mutual interaction between people of different professions – a kind of "symbiosis" [4, 5], in which flows of matter, energy and information as a system were more efficiently used. At this stage, the differentiation of professions took place and plants appeared with their further integration on the basis of greater benefit and complementarity "mutualism" [4, 5], creating a more comfortable and safe conditions for the life of the population in cities [1, 3, 6, 11, 12].

DEVELOPMENT POTENTIALS

We know that effective development of system is based on the increase of order in it. "The order is defined as the conditions for sustainable (continuing relatively long period of time) directed changes" [12, p.29]. For order formation in a certain place, this part of the space shall be organized in a certain way at the informational level and internally regulated to give the occurring changes stable directional character. But for this, first of all, the system has to have a certain energy potential, able to bring any changes and movement to life [12, p.31].

As for the potential of ecological and city-planning system. The ecological potential of this system is determined by the climatic conditions and regional resources and is measured by demographic capacity (the ability to accommodate, feed and provide a comfortable living conditions for certain, maximum possible quantity of stable population) [11]. City-planning potential of this

system, in addition to social and cultural, engineering and transport potential, is determined by the production potential, which is measured by its economic capacity (the ability to provide the population with jobs for effective and sustainable development of the industrial production in various areas of industrial activity based on resource natural features of the territory and recovery of resources [14].

The measurements of the aforementioned potential to a certain extent are inversely related: with a significant increased of one of them, the value of another indicator can be greatly, sometimes like an avalanche, reduced. The energy difference of potentials violates the ecological balance of the system. However, this imbalance is a driving force of its quantitative and qualitative changes [12, p.32]. The positive direction of the vibrational changes results in conversion processes of development of "population ↔ environment" to a new level of spatial integrity [11, 15].

Development of the system can be interpreted as a process of accumulation and transformation of energy, for that it should be open. The system of "population ↔ environment" as an open system, to support of its sustainable development and restoration of ecological potential uses inflows and the accumulation of solar energy in agricultural products, livestock, forestry and fisheries, minerals, ecophile technologies of energy production. City-planning potential development of the system is due to the production of human activities that create and accumulate wealth in the construction of residential, civil and industrial buildings; roads, vehicles and buildings; buildings of public utilities, engineering preparation, planting and watering of areas; objects of culture, education, science and communication, military and defense industry, and so on. The guarantee of sustainable development of this system is the harmony (mutual coherence) of the aforementioned potential [4, 6, 9, 11, 12].

ECO-PHYSICAL PARALLELS

The spatial ordering of the system provides its structure, which usually refers to the location in space of its individual parts and a set of stable relations between them [12, p.31]. In the city-planning understanding this order is provided by already mentioned structure and infrastructure of city-planning facility [8, 9, 17, 18]. The information ordering of the system provides constant focus organized in space and time of its material and energy flows as the basis for its operation and development [12, p.31]. In city-planning it is provided by a regional policy, strategy and tactics of management, city-planning programs and plans of territories development [7, 8, 18, 19, 20] which, in our study [11, 15], should take into account the fundamental law of open systems – the law of conservation of power (Lagrange, 1788; Maxwell, 1855) [3].

In the plane studied, this law appears to be the law of ecosystem self-regulation [6]. According to this law, in the conditions of "under-population" of the area, the number of population grows, under the conditions of "overpopulation" reduces. The study found that the development of ecological and city-planning system, as well as mechanical and electromagnetic fluctuations (according to P.Ya. Myakishevyy, B.B. Bukhovtsev), has a wave nature [11, 15, 16]. Similarity refers to the natural process of periodic changes (Tab. 1).

SPATIAL-TEMPORAL DIMENSION

According to J. Maxwell, A. Puankare, M. Bor, A. Einstein, R. Bartini, P.G. Kuznetsov, a physical value is universal, if and only if its relationship to space and time is clear [3, p.162]. In city-planning development, the connection with space and time was studied by Z. Hydeon, M.M. Habrel, M.M. Domin, A.M. Plyeshkanovska, V.O. Tymokhin, N.M. Shebek and others. However, identifying of analogies shown in Tab. 1 gave an opportunity to take the next very important step for the development of city-planning science, namely to translate key dimensions of ecological and city-planning system "population

Table 1. The analogy between indicators of ecological and city-planning system (ECPS) mechanical and electrical quantities

Mechanical	**Electrical quantities**	**Indicators of ECPS**
mass (m)	inductance (L)	population (P)
coordinate (x)	charge (q)	capacity = maximum number of stable population ($C=P_m$)
speed ($v_x= x'$)	current ($i = q'$)	population dynamics (P')
acceleration ($a_x= x''$)	electromagnetic waves in the circuit ($q''= -q /LC$)	growth-rate decline (P'')
elastic force ($F_x= -kx$)	resistance circuit (R)	environment resistance ($1 – P/C$)
spring stiffness (k)	reciprocal capacity ($1/C$)	stiffness of environment ($1/C$)
potential energy ($k x^2/2$)	electric field energy ($q^2/2C$)	potential «electric» energy ($C/2$)[1]
momentum ($mv_x^2/2$)	energy magnetic field ($Li^2/2$)	implemented «magnetic» energy ($P_\Delta P^2/2$)[2]

Notes.

1. Agreed with data of Y. Odum: "Optimal maintenance capacity that can be stored for a long time, despite the whims of the environment, below the theoretical limit, perhaps by 50%" [4, part 1, p.180].
2. May explain some mentioned attractiveness of urban areas.

↔ environment" into the language of universal spatial-temporal [LT] physical quantities [3, p.47].

It is well known that for the city-planning facilities the original [$L \leftrightarrow T$] values are length [L^1], space [L^2], volume [L^3] and time [T^1] of existence in the environmental area. However, the question arises how the spatial-temporal dimensions are related to the population – an important characteristic of ecological and city-planning system?

According to O.L. Kuznyetsov, referring to the article of R. Bartini "The Relation Between Physical Constants", "all physical quantities are of spatial-temporal nature and can be derived from two variables: length and time" [3, p. 162]. He points to the opportunity to bring all physically measurable quantities from two major ones and present them as a product of integer degrees of length [L^R] and time [T^S], which under various R and S give: dimensionless constants [L^0T^0], geometry objects [L^RT^0], "time" and "frequency and time" measurements [L^0T^S] (Tab. 2) [3, p.162].

It appears that in his time J. Maxwell in his treatise "On Electricity and Magnetism" (1873) set the relationship of dimension of "mass" (with its designation in brackets) with space and time [3, p.151]. According to Maxwell, the spatial-temporal dimension of mass has dimension [L^3T^{-2}] – of volume [L^3T^0] with angular acceleration [L^0T^{-2}]. The "functional" similarities of population to body weight we found out (see Tab. 1) gave an opportunity to present the main indicators of ECPS development in the language of universal spatial-temporal variables (Tab.3).

The most important among the results obtained is a measure of population density and demographic acceleration capacity as a power. These results coincide with the fundamental laws of historical development of O.L. Kuznyetsova: time saving law (display of acceleration of socio-economic development) and net power growth law (expression of cumulation of "free energy" in system "nature – society – man"). The free energy of ECPS development, in this case, is the stock of the demographic capacity. The specified

Table 2. Periodic system of space-time physical quantities by R. Bartini, P.G. Kuznyetsov

T^{-6}					Change of power	Transfer rate of power
T^{-5}		Change of pressure	Surface power	Rate of change of force	Power	Transfer rate of energy
T^{-4}	Change of current density	Pressure	Angular acceleration of weight	Force	Moment of force. Energy	Transfer rate of action
T^{-3}	Current density	Intensity of the electromagnetic field. Gradient	Current. Mass flow rate	Velocity of charge. Pulse	Moment of momentum. Action	Moment of action
T^{-2}	Acceleration	Potential difference	Mass. Number of magnetism and electricity	Magnetic moment	Moment of inertia	
T^{-1}	Speed	Mobility of 2 dimensions	Volumetric flow rate	Rate of volume displacement		
T^{0}	Length. Self-induction	Surface	Volume			
	L^{1}	L^{2}	L^{3}	L^{4}	L^{5}	L^{6}

result is of fundamental importance because it coincides with the little-known definition of sustainable development as "free energy sustainable growth" (UNDP "Sustainable Development of Cities", Moscow, 1999) [3].

In the periodic system of physical quantities in the $L^{R}\leftrightarrow T^{S}$ interaction process, symmetry axis is formed, which has symmetrically inverse $L^{K}T^{-K}$ «axial» invariants having the same dimensions, but different sign. "Axial" invariants differ in speed and are located on levels in the order of growth: Level 1 – $[L^{1}T^{-1}] = [V^{1}]$ speed; Level 2 – $[L^{2}T^{-2}] = [V^{2}]$ potential difference, "square-speed"; Level 3 – $[L^{3}T^{-3}] = [V^{3}]$ current "cub-speed"; Level 4 – $[L^{4}T^{-4}] = [V^{4}]$ force; Level 5 – $[L^{5}T^{-5}] = [V^{5}]$ power; Level 6 – $[L^{6}T^{-6}] = [V^{6}]$ transfer rate of power (see Tab. 2) [3, p.163]. For P.G. Kuznetsov, *LT* system of physical quantities is hierarchy of nested measures – a kind of "matryoshka" measurements, the apex of which is the capacity $[L^{5}T^{-5}]$, in this case, it is the demographic capacity that characterizes the maximum number of stable population [3, p. 164].

According to the periodic system, formation of speed axis vector is two-stroke transfer from one axial invariant (in our case – the spatial level of ECPS integrity) to another with increasing speed qualities (in this case with the change of possibilities of movement of in space the population, matter, energy and information). During the first stroke of forming, the leading vector in space is determined, in our case, the priority direction and spatial level of territorial development of the city are determined: local – by the resources of surrounding areas or regional, national and global (Global City) – at the expense of resources away from the cities, areas. During the second stroke, the leading vector in time is formed, in our case – is determined by the sequence of city-building regulatory effects, depending on the phase of the cycle of multilevel city development in regional and global dimensions of the environmental space [11, 15]. By analogy with Tab. 2, we built a periodic system of spatial-temporal changes occurring in ECPS (Tab. 4). This table is likely – to provide an opportunity to deeper penetrate into the eco-physical nature of urban and ecological processes of development and

Table 3. Spatial-temporal dimensions of status indicators, direction of changes and the potential of development of ecological and city-planning systems and "population ↔ environment"

Ecological and city-planning index	**Units of mesurement or expression**	**Physical analog**	$L^R T^S$ **coordinates**
Spatially (L) – temporal (T) distances between settlements	Km, hours	path length, travel time	L^1T^0 L^0T^1
The period in question (T)	year, hour	period	L^0T^1
Travel speed (L/T)	km/h	speed	L^1T^{-1}
Population (P)	thous. people	mass	L^3T^{-2}
Capacity – maximum number of stable population (C)	thous. people for a specified period of time and a specific territory	power	L^5T^{-5} = const
Population Dynamics (P')	thous. people/year	current	L^3T^{-3}
The rate of population growth - reduction (P'')	attraction – repulsion	angular acceleration of (deceleration) weight	L^3T^{-4}
Resistance to the environment ($1 - C/P$)		tension of electromagnetic field	L^5T^{-5} / L^3T^{-2} = L^2T^{-3}
Tightening of environment ($1/C$)	1/thous. people	value of the inverse power	$L^{-5}T^5$
The annual potential energy ECPS ($C/2$)		electric field region	L^5T^{-5}
Implemented energy ECPS ($P\cdot{}_{\Delta}P^2/2$)		magnetic field of the city	$L^3T^{-2}\cdot(L^3T^{-3})^2$ = L^9T^{-8}
Area of city, region (S)	thous.km^2	surface, area	L^2T^0
Dynamics of city area, region (${}_{\Delta}S$)	thous. km^2/year	mobility of 2 dimension	L^2T^{-1}
Population density ($\rho=P/S$)	people/km^2	acceleration	L^3T^{-2}/L^2T^0 = L^1T^{-2}
Ecological equilibrium space module of life support of a person ($M = S/P$)	km^2/ person	no corresponding physical value now	$L^{-1}T^2$
Comparison of potential in a specific period ($C/P\cdot T$)	possibility of growth	potential difference	$L^5T^{-5}/(L^3T^{-2})\cdot T$ = L^2T^2
Reserve of demographic capacity in a particular area for a specified period for development (amount of time) ($C - P\cdot S/T^3$)	thous. people in a particular area for a specified period of time	«free energy» development of a system in specified period of time	L^5T^{-5}
Migration of population (reversible and irreversible) – the number of people who moved in space with a certain speed	thous. people in a particular area for a specified period of time moving in space	«mobility», speed of transfer of power	L^6T^{-6}

Table 4. Spatial-temporal dimensions of change processes of ecological and city-planning systems

T^{-6}						Mobility
T^{-5}			Acceleration of number change		Demographic capacity	
T^{-4}			Rate of population change			
T^{-3}	Changes in population density	Resistance to the environment	Population dynamics			
T^{-2}	Population density. Acceleration of movement	Speed of changes of area	Population.Growth of constructed area			
T^{-1}	Movement speed	Change of area. Active suface	City construction			
T^{0}	Radius of contacts	Area of city, region	Spatial volume			
	L^1	L^2	L^3	L^4	L^5	L^6

take account of the impact of the next speed-hierarchical level of mobility [L^6T^{-6}] that captures the speed capacity. In our case, it analogous may be population mobility, which greatly accelerates the life processes of population and transfers the development of the entire system to a new level of space development.

CONCLUSIONS

1. The growth of population density that has acceleration dimension, causes the gradual expansion of spatial limits of ECPS. The abovedefined reveals the theoretical basis of scientifically proven management of sustainable development of ecological and city-planning systems due to city-planning opportunity to accelerate and slow down urban processes by changing their spatial boundaries and population density.

2. Representing in [LT] dimensions of indicator of changes in population density over time, reveals the physical nature of this indicator as the current density [$LT^{-2}/T = LT^{-3}$]. population dynamic [$L^3T^{-2}/T = L^3T^{-3}$] has physical value of current in ECPS. The above defined indicates the likelihood of a new dynamic characteristics of sustainable development, which detects the oscillating uneven distribution of density changes and the population dynamics, which change creates ripples and surges in business activity in the ECPS.

3. Representing in [LT] dimensions of indicator of changes in population density in three-dimensional space, as [$LT^{-2}/L^3=L^{-2}T^{-2}$], reveals the physical nature of this value as the third derivative of the change in permeability [$L^{-2}T/T^3 = L^{-2}T^{-2}$] over time [3, p.162]. Spatial uneven population density of ECPS is "gravity-magnetic surge" of intensity of land invasion at different levels of spatial integrity. On the one hand, these bursts contribute to the growth of cities (benefits from population concentration and production), on the other – the accumulation of regional differences in the land invasion and "depopulation" regions.

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ПРОСТРАНСТВЕННО-ВРЕМЕННЫЕ МЕРЫ И ОСНОВЫ УСТОЙЧИВОГО РАЗВИТИЯ ЭКОЛОГО-ГРАДОСТРОИТЕЛЬНЫХ СИСТЕМ

Аннотация. Изложены результаты исследования фундаментальных основ устойчивого развития эколого-градостроительных систем. Определена возможность использования фундаментального закона устойчивого развития открытых систем – закона сохранения мощности. Установлены пространственно-временные меры эколого-градостроительной системы «население ↔ среда».

Ключевые слова: эколого-градостроительные системы, устойчивое развитие, экологическое равновесие, демографическая емкость, пространственно-временные измерения.