Innovative programming product for work architect-urbanist with Big Data of city

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Abstract. The article substantiates the necessity of creating an innovative programming product "Program complex for modelling the city as a dynamic system". The methodological basics of writing a technical task as the basis for the complex development are described. The aspects of its use as a tool for information support of strategic decision-making processes related to the transition of the city to an intensive type of development are disclosed. The purpose of the program complex: information support for strategic decision-making processes to optimize the principles of the city. The purpose of the program complex is to analyze the processes of city functioning as a complex dynamic system. In this case, it is possible to diagnose the current state of the city as a system in real-time, the state of its subsystems and elements, as well as to predict changes in the dynamic processes of their functioning. The specified program package is based on a combination of two trends in modern science: optimization of the city functioning processes and management of large arrays of city data (Big Data). The Program simulates positive and negative dynamics of the transition of the city, its subsystems and individual elements from a state of stability to crisis and a possible pre-catastrophic state.

1. Introduction

According to the authors, the main problem in the development of modern cities is the actual impossibility of relying on thousands of years of experience of the architect's speciality in shaping the appearance of post-industrial architecture. The modern post-industrial city is forced to transform under the pressure of the new realities of the time. This refers to the fourth industrial revolution, the demographic transition, the globalization of economies, the scarcity of vital resources, the aggravation of ecological factors, and many other aspects that the development of our civilization has brought to the city.

The motivation for this study was the experience gained by the authors in the process of analyzing the problems of residential areas in Kharkiv, mainly built up with obsolete housing. The acuteness of the problem lays in the fact that 65% of the housing stock in large areas of population had reached the end of its design life. The problem was that against the background of a fairly active construction of new housing, only one obsolete house was reconstructed in accordance with the Ukrainian legislation
on energy efficiency of buildings. An in-depth analysis of the revealed phenomenon showed that the level of social, economic and resource crises has reached a stage that threatens the sustainable development of the city [1]. The close interweaving of hundreds of various factors, complicated by the collapse of social relations within the urban community, does not allow the city to realize its rather high potential.

In search of algorithms for possible solutions to the residential and related socio-economic crisis, 284 architectural and urban planning dissertations were investigated. Of the entire array of works, only seven authors: Chabanyuk O. [2]; Litoshenko G. [3]; Morklyanyk O. [4]; Andrianova G. [5]; Bilokon Y. [6]. The authors offer fragmentary solutions to the problem raised. This means that the situation is potentially capable of bringing at least 25% of the inhabitants of Ukrainian cities to the brink of an acute crisis.

Over the past 5 years, many DSTU - normative documents have been adopted in Ukraine, regulating the principles of sustainable urban development. These documents are part of the process of harmonization of Ukrainian standards with international ISO standards. The initial regulatory documents for the analysis of the problem of sustainability of morally obsolete residential areas were such standards as:

- ISO / TC 268 Sustainable cities and communities [7];
- ISO 37153 Smart community infrastructures - Maturity model for assessment and improvement [8];
- DSTU ISO 37101 Sustainable development in communities - Management system for sustainable development - Requirements with guidance for use., and more than 30 related standards related to sustainable development principles [9].

Taken together, these standards set the main parameters for changing the principles of life in the areas under consideration. At a certain moment, the understanding came that the amount of information that must be taken into account when solving this type of problem is so great that it significantly exceeds the psychophysiological abilities of any person. The study of existing programs for managing large amounts of data did not reveal an unambiguously finished product for use in difficult conditions of multiple systemic crises. Therefore, in the process of research, the need to develop its own software product arose.

The theoretical basis for the formation of an innovative software product was the work of Donella Meadows - "World 3" [10], [11], [12].

2. A Program package for modelling the city as a dynamic system
The purpose of the program complex: information support for strategic decision-making processes to optimize the principles of the city.

The purpose of the program package is to analyse the processes of functioning of the city as a complex dynamic system. In this case, it is possible to diagnose in real-time the current state of the city as a system, the state of its subsystems and elements, as well as to predict changes in the dynamic processes of their functioning. The specified Program package is based on a combination of two trends in modern science: optimization of processes of city functioning and management of large arrays of city data (Big Data).

The program simulates positive and negative dynamics of the transition of the city, its subsystems and individual elements from a state of stability to crisis and a possible pre-catastrophic state. The methodological basis for the development of the program package is the system dynamics methods [13]. According to these methods, the totality and mutual influence of all dynamic processes in the city system
determine the parameters of its functioning. The strength of these changes, their speed and acceleration form certain requirements for the organization of the city as a system.

The program complex consists of two hierarchically connected but autonomously organized modules:
1) Cognitive-research matrix of identifying and analysing problems of the city as a dynamic system (Matrix).
2) Information- accumulative interactive model (Model).

3. Cognitive-research matrix to identify and analyze the problems of the city as a dynamic system (Matrix)

Cognitive research matrix is a program product compiled by basing on methods: multidimensional matrices; tabular parameterization; statistical analysis; cognitive science and system dynamics. The matrix interface is formed based on the multidimensional matrix method and is designed as a table template.

The multidimensional matrix method is based on the principle of a systematic analysis of new relationships and relationships that are identified in the process of morphological analysis of the problem under study. The essence of the method consists of combining into a single system of methods for identifying, designating, counting and classifying all selected options of any function of the object of study.

Morphological analysis is carried out according to the following scheme: 1) formulation of the problem; 2) statement of the problem; 3) compiling a list of all characteristics of the examined object; 4) compiling a list of possible options for describing each characteristic [14].

In the simplest case, a two-dimensional morphological map is compiled by using the method of morphological analysis: two most important characteristics of the object are selected (in the template “Cognitive-research matrix” these are “Needs” and “Artifacts”, see below), where each of them is used to make a list of all possible forms of exposure, then a table is built, whose axes are these lists. The cells of such a table correspond to the options for describing the investigated problem. In this case, the city is studied as a system, so each cell is an embedded morphological box. This means that the variant obtained from the intersections of the characteristics of the research object itself becomes the object of study and takes place in a new table, describing its characteristics.

In the cognitive-research matrix, the three columns of the template table describe the groups of artefacts of the city's subsystems - “Technosphere”, “Ecosphere” and “Population”. The lines indicate the city needs that must be satisfied so that the city functioned as a stable system. For example, social, energy, resource, food, natural, economic, industrial, etc. At the intersection of a row and a column, a “cell” appears, which contains information about events meeting the needs of the city (hereinafter “Case of events”) (table 1).

| Object research | Subsystem | Population | Technosphere | Ecosphere |
|-----------------|-----------|------------|--------------|-----------|
| Needs           | A         | B          | C            |           |
| Demographic     | 1         |            |              |           |
| Agriculture     | 2         |            |              |           |
| Environmental   | 3         |            |              |           |
| Energy          | 4         |            |              |           |
Each “Case of events” is an information package and carries the functions of an embedded morphological box. The information component of the “Case” is an information package generated in the process of the cognitive-research matrix and transmitted to the information-storage model of the city. The collection of all information packets generated by the matrix is the basis of the array data model.

To form the matrix information package, the “Case of events” template was developed. The template contains a block of verbal information describing meaningful context case and a statistical information block.

**Figure 1.** Case of event template.

The block of verbal information of Case is part of the methods of cognitive science embedded into the cognitive-research matrix. This block is formed by an expert working with the Matrix and consists of a verbal description of a possible (according to the expert opinion) event that arising as a result of satisfying needs of the city. Description of the event is carried out arbitrarily based on the generated matrix keywords triples. Keyword №1 - characterizes an artefact belonging to one of the subsystems of the city of the Ecosphere, Technosphere, Population (Columns of the matrix). Keyword №2 - characterizes the needs of the city (Matrix Rows). Keyword №3 - characterizes the object of the study.
The third keyword is a constant that is attached to each cell of the matrix and allows you to specify and limit down the field of scientific research.

The statistical information block contains the following data:
- Case identifier, consisting of coded information that allows you to determine the matrix to which Case belongs, the expert who completed the Case template, the date of filling and encoding of information cells that make up the Case information package (figure 1.2);
- cells containing links to statistical information related to the keywords of the Case of event. For example, Keywords: pensioners (artefact “Population”), purchasing power (need “Economic”), deductions for modernization (object of research “Energy Efficiency”) (figure 1.6). The first cell statistically describes the increase in the housing stock of the number of people of retirement age for the study period (in the experiment from 1965 to 2019), the second cell describes the increase in the welfare of pensioners and the third increase in the contributions made by pensioners to modernize the building in which they live. For each of the three cells, based on calculations of the “underlying rate of growth” a dynamics graph for either artefact functioning or needs is built. Based on the graph vector dynamics is calculated, on which the cell indicator dynamics is built. The indicator is a graphical interface for data output developed for research (figure 1.7);
- a verbal description of the event, for example: “Loss of purchasing power of the retirement age public in housing estate is a significant problem, aggravating the energy modernization of buildings” (figure 1.5);
- coordinate attachment of Case contents to the space of the city (based on GIS) (figure 1.6);
- the type of resource to which the contents of the Case belong (social, natural, or technogenic) (figure 1.7);
- an indicator that, based on statistical data, provides an assessment of the current dynamic state described by the Case of event and the predictor of its future condition to the horizon of predictions established in the study (figure 1.7);
- the coefficient of the Case significance, which determines the hierarchical dependence of the case in the overall information structure of the database (figure 1.7).

Each “Case”, being an embedded morphological box, is able to expand into a new matrix template that describes a lower hierarchical level of functioning of the city.

Due to the methods developed by forming the structure of cognitive research matrix, program complex had the opportunity to: fix the cognitive map representations of researchers about the city, its subsystems and elements; identify cognitive distortions of ideas about the city; create and adjust group, interdisciplinary cognitive maps; identify the necessary expert profiles and form multidisciplinary research groups; create information packages describing the principles of the city’s functioning and establish parametric connections between these packages; to form a database, which is the basis for the functioning of the second part of the program complex - “Information-storage interactive model of the city as a dynamic system” (hereinafter “Model”).

An example of working with a matrix template and case of event is given in a section of this article devoted to an experiment on verifying the operability of research methods embedded in a cognitive research matrix.

4. "Information-accumulative interactive model of the city as a dynamic system" ("Model")
The model contains large data arrays (Big Data), consisting of information cells. An information cell is an information unit that can contain various types of data (text, numbers, dates, etc.), but only one type of data can be stored inside one cell. At the time of the transfer of “Cases of events” from the Matrix to the Model, their information packages are distributed among the Information cells. At the same time,
genetic connections between the cells that make up the “Case of events” are preserved. Each cell, potentially, can belong to an unlimited number of information packages, which allows you to establish parametric relationships between the “Cases of events”.

The totality of the accumulated and pooled data model reflects the overall dynamics of the functioning of the city as a system.

The structuring of information in the information storage model takes place in three main areas: geographic referencing (coordinates in the GIS and clustering of data on a geographical basis); by belonging to the main subsystems of the city (Ecosphere, Technosphere, Population), by the hierarchical dependence of “Cases of events” built up by the sequential disclosure of the matrix templates. The connections established in this way, in turn, allow you to simulate the response of the system to changes in the functioning parameters of individual elements and subsystems, as well as to localize and track the dynamics of the processes occurring in the city.

The method of content analysis serves as a methodological basis for conducting targeted research of the city as a system. The basis of content analysis is the counting of the occurrence of some components in the analyzed information array, supplemented by the identification of statistical relationships and the analysis of structural relationships between them, as well as supplying them with various quantitative or qualitative characteristics [15].

Information packages of “Cases of events” contain a verbal component. Due to the content analysis method, it becomes possible, using sets of keywords set by an expert based on the research object, to form thematically integrated information blocks. At this stage of the selection, the information is chaotic and has no structure.

The basis of the Information blocks is the information cells of the sampled “Cases of events”. Each Information cell has a set of genetic and parametric relationships, which allows you to select data from the selected array according to the following criteria: territorial — a set of information blocks in a given search radius; event - information blocks belonging to one group, or close templates disclosure matrix; typological - groups of information blocks belonging to the same type of subsystems segments “Ecosphere”, “Technosphere”, “Population”. The information blocks formed by the method described above are called “Symptom complexes” in a further study.

For example, in the experiment described below, the automated formation of the Symptom complex was simulated by the following set of keywords: cases of vandalism; increased energy efficiency; the price per m2 of secondary housing: $ 1,000 - $ 750; 749 - $ 500; 499 - $ 250; the growth of self-organization UBFW (The union of a block of flats owners). The imitation consisted in identifying key aspects of the functioning of the housing estate “Novi Budynki” in Kharkiv and putting them on a map of the area. At the end of the work, a round pattern made on a map scale with a radius of 300 m was used to group information cells into symptom complexes according to territorial criteria. Due to this approach, four Symptom complexes were identified that indicated segments of the housing estate with negative socio-economic dynamics, and two with a positive one.

The nature of the tasks solved with the help of the “Information-storage interactive model of the city as a dynamic system”:
- collection and storage of large amounts of data about the city;
- diagnostics and forecasting of the state of the city as a dynamic system, monitoring the transitions of the city system and its subsystems from resistance to crisis and possible disaster;
- based on the compiled “Symptom complexes”, the automatic formation of the indicators “Sustainability”, “Crisis” and “Catastrophe” pointing positive or negative dynamics of the city;
- automatic generation of “Knots of problems” based on identified indicators. “Knots of problems” - contradictions between the principles of functioning of individual elements and subsystems of the city among themselves, which result in the growth and accumulation by the city system of errors that could potentially lead to a crisis or disaster. Each identified and formed knot of problems implicitly contains information about the points in his effort remedial applications;
- identifying "agents of change", allowing to adjust the functioning of the dynamic processes of the city without losing their accumulated positive properties;
- prediction of resource consumption required to correct the negative dynamic processes;

The developed model complex allows you to:
- interactively simulate the behaviour of the city system in the context of constant data changes;
- predict directions that are potentially dangerous for the stable functioning of the city system. Due to this, determine the urgency and importance of making the necessary decisions to identify the threat of system errors that can critically affect the situation in the city;
- analyze the reaction of the city system to planned activities to optimize the processes of its functioning and create prognostic maps of these reactions, identify causal relationships and the hierarchical structure of the described processes to assess the strength of their influence on the city system;
- identify the sequence and relevance of events that can provoke the city system to positive changes without losing its positive qualities.

5. Conclusions
The basic needs of city residents in water, air, food, and shelter are satisfied with limited resources. Environmental pollution accumulates, nature is not able to process. In modern cities, there are practically no other options left, except for the development of the principles of intensive environmental management. This means that the functioning of each city should be based on renewable resources of the adjacent territories. Such radical changes are always associated with the aggravation of the social, technological and environmental crisis. The price of mistake here can be a critical loss of resources and a possible depopulation of large cities of the country.

The aim of the study presented in this article was an attempt to create a universal tool responsible for information support of strategic decision-making processes for managing and updating the principles of functioning of cities as complex dynamic systems. The “program complex for modelling the city as a dynamic system” was developed as a complexly compiled product with multi-level non-linear logic and a simple interface. The materials presented in the article are the theoretical basis of the technical specifications for the currently designed program product. The authors have great hopes for the discussion with experts who may be interested in the presented materials.

In Ukraine, there is almost no long-term strategy for the transition of the country's cities to an intensive type of management. This fact holds back the development of scientific and educational programs focused on the development of socio-economic models of cities, the principles of which are based on integration into the natural environment.

At the same time, it should be emphasized that the complex of environmental, social and technological crises currently being experienced by Ukrainian cities may become characteristic of the cities of the European Union in 15-25 years. For this reason, the cities of Ukraine can and should be considered as a unique base for conducting a large-scale practical experiment to achieve their sustainability in the face of many system restrictions.

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