Digital transformation in land use and cadastre: towards adaptive cadastral systems

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Abstract. The article considers one of the key aspects of transformations taking place with modern cadastral systems in the context of globalization, integration and digitalization of the surrounding space and economy. It is revealed that the transformation of existing functions of national cadastral systems in the transition to digital economy will obviously lead to the emergence of new properties of cadastral systems, in particular to the emergence of properties of adaptability. The study shows the regular stages of development of the functions of cadastral systems for each time stage, proving that the functions performed by the cadastral system are not static; they change as the economic system of society changes. From the point of view of system conceptions, the development of cadastral system follows a logistic curve and includes the stages: emergence of cadastral system and functions, stabilization of functions, their qualitative development, specialization of functions. Each stage is accompanied by the process of function deployment (winding up) under the influence of the processes taking place in the economic system and society. The emergence of the property of adaptability in the near future of cadastral systems will contribute to the emergence and development of a whole bundle of functions of national cadastral systems, aimed at adapting these systems to the environment of their functioning. The emergence of this new feature is necessitated by the ongoing digital transformation of land-use systems as a response to the challenges facing the global land-use system.

1. Introduction
The transformations taking place in the world today are based, for the most part, on the processes of globalisation, integration and digitalisation of the environment and the economy embedded in it. The changes laid down by the digital economy paradigm undoubtedly affect many areas of developed economies, but are of particular importance in the area of land and other real estate.

The territory, as a projection of economic space, is saturated with various objects: land plots, capital construction objects, engineering infrastructure, zones with special conditions of territory use, borders of different levels (country, its regions, municipalities) and other objects, location, area, and many other data about which are contained in national cadastres (registers) of rights and real estate. At the same time, the relevant issue of the existence and development of such systems, along with the accuracy and reliability of their data, has always been the sufficiency of cadastral data to address land management issues.

Modern cadastral systems have become increasingly complex over time: the external environment in which society's economic system operates through the transition to a digital economy is changing,
methods and techniques of cadastral survey production are improving, and information technology for cadastral surveys is becoming more sophisticated.

Active development of globalisation processes prevents cadastral systems of states from developing in isolation, which is primarily due to the commonality of global economic development, as well as the commonality of problems to be solved and global challenges to national cadastral systems. And if at the beginning of its emergence the cadastral systems of states, developing in accordance with their ideas about specialisation, contributed to the emergence of legal (legal) cadastre and fiscal (tax) cadastre, then the modern trend of development of cadastral systems of states has been its multifunctionality for a long time. Although multifunctionality better provides answers to the challenges faced by national cadastral systems, its problematic aspect may be the redundancy of cadastral information and the functions performed by the system [1-3].

The unity of globalisation, integration and digitalisation of the environment and economy as the main trend of modern development will objectively lead in the coming years to the emergence of new properties of cadastral systems, in particular to the emergence of properties of adaptability.

2. Models and methods

The object of the study is the cadastral system of the state, the subject of the study is the system and functional regularities of cadastral systems development.

This study uses a systems approach and general provisions of systems theory. The use of the systems approach made it possible to consider the cadastral system of the state as a dynamic object of research, taking into account the numerous links (interaction mechanisms) and relationships that arise at each stage of the development of the system under study.

The systemic and functional regularities of the development of the cadastral system of the state are revealed using the provisions of the theory of systems.

3. Results and discussion

Our research, conducted earlier on system regularities of the state cadastral system functioning [4] and transformation of its functions in historical development [5], allowed us to identify some regularities, according to which the modern cadastral system of Russia will develop. Let us briefly outline our findings.

The functions performed by the cadastral system are not static; they change as the economic system of society changes. From the point of view of the system concept, the cadastral system development follows the logistic curve. Figure 1 shows an example of supposed development of the modern cadastral system in Russia (solid lines indicate the actual development, dotted lines - supposed development derived from the identified patterns of cadastral system development taking into account general provisions of systems theories [6]).

The creation of the State Real Estate Cadastre in 2008 was a milestone in the development of Russia's modern cadastral system. It was this cadastre that became the legal successor of the State Land Cadastre and set the conceptual principles in the form of unified approaches and principles of maintenance throughout the country, regardless of the category of real estate objects, and digitalization of its maintenance. At the same stage there were prerequisites for transformation of the State Real Estate Cadastre into the Unified State Real Estate Cadastre, which took about 9 years. These prerequisites were: unification of cadastral land and capital construction registration systems, as well as convergence of registration and title registration systems.

The modern stage - the stage of stabilisation of the cadastral system functions - was marked by the transformation of the cadastral system into a state real estate registration system by combining state cadastral registration and state registration of rights into a single system.

The new knowledge and digital economy, which is shaping new digital skills and opportunities for society, business and government [7], has been dubbed the digital economy, and this is the starting point for the emergence of new functions of the cadastral system.
Figure 1. Functional patterns in the development of cadastral systems (using the example of the post-Soviet cadastral system of the Russian Federation).

Legend: 0 - 1 is the emergence and establishment phase of the cadastral system;
1-2 - Stabilisation phase of the functions of the cadastral system - accompanied by a process of function deployment (winding down) under the influence of the processes taking place in the economic system and society. During this phase, new functions may emerge and/or existing functions may be discontinued (temporarily or permanently);
2-3 - stage of qualitative development of cadastral system functions - is also accompanied by the process of winding down (unfolding) of functions, but differs from the previous period in that the final qualitative saturation of each system function occurs, their specialisation which in future can serve as a basis for the formation of new systems;
3-4 - cadastral specialisation stage - is the final stage of system development and implies specialisation of the cadastral system by singling out individual functions, i.e. the emergence of monofunctionality.

Let's take a closer look at the regular stages of function development (figure 2). The emergence of the cadastral system coincides chronologically with the emergence of the functions (figure 2 point a).

In general, the stage of emergence of functions is characterised by:

- the multifunctionality of the cadastral system, which manifests itself in the performance of multiple functions by all elements (subsystems) of the system, in the absence of clear specialisation of individual elements (subsystems) in the performance of individual functions;
- weakly developed functions - the functions of the system are not clearly separated from each other, are often undeveloped or underdeveloped, and exist as functional areas.

The transition from the emergence of functions to the development of functions is associated with the initiation of stabilisation processes within the inventory system. Graphically, the transition to the function development stage occurs at point b1 at the intersection of the function life cycle curve and the cadastral development curve. The function development stage corresponds to the stages of stabilisation and qualitative development of the cadastral system and is characterised by the following:

- development of the existing functions of the cadastral system, i.e. a qualitative transformation of the set and structure of the basic functions of the state's cadastral system;
- the emergence of new functions of the cadastral system as a result of the development of the cadastral system as a whole, and also as a response of the system or its individual elements to changes in the external environment.
At point d, there is a divergence between the life cycle curve of the functions and the development curve of the cadastral system, thereby causing a transition to the stage of functional improvement, which is characterised by:

- deletion of unnecessary functions, i.e. functions that have duplication, functions that are not in line with the development objectives of the system at this level;
- the quality improvement of the functions used by the system (transition to monofunctionality), which manifests itself in the form of fixation (specialisation) of a single element of the system (subsystem) to perform a particular function.

**Figure 2.** Laws of deployment (winding up) of the functions of the cadastral system (by the example of the Old Russian cadastral system)

Legend:
- segment a - b the emergence of a new cadastral system;
- point a - the emergence of the cadastral system function (e.g. the accounting function in the Russian cadastral system in the ninth century);
- segment b - c - the stabilisation phase of the development of the functions of the cadastral system;
- point b1 is a qualitative transformation of a function (e.g. a quantitative accounting function);
- point b2 - the emergence of new forms of function (e.g. new forms of land quality records);
- point b3 - development of the function (e.g. development of the land valuation function as part of land quality accounting);
- segment c - d - stage of qualitative development (improvement) of the functions of the cadastral system;
- c1 - the withering away of generalised functions (e.g. the land valuation function within qualitative land records);
- c2 - qualitative improvement of the function (e.g. quantitative land records);
- c3 - qualitative improvement of the function (e.g. land quality records);
- segment d - a - transition to the new inventory system through attenuation (transformation) of functions;
- d1-1 - the final die-off of non-essential (generalised) functions for the cadastral system;
- d1-2 - conversion of individual functions of the cadastral system into specialised systems (e.g. land valuation functions into a specialised valuation system).

The decay (transformation) stage of the functions is shown on the d - a curve segment, to which point d belongs, marking the end of the period of development of the cadastral system. The point d divides the decay (transformation) period of the functions into two distinct half-periods:

- d1-1 to d1-2 - characterised by the final specialisation of individual system elements to perform individual functions, i.e. a manifestation of monofunctionality;
- d1-2 - a - is characterised by the emergence of signs of inability of functions to achieve the main purpose of the cadastral system and the transformation of existing functions to a qualitatively new level.
Functional development stages are possible through deployment (expansion of system functionality) and phase-out (elimination of redundant and harmful system functions) mechanisms of cadastral system functions.

As follows from systems theory, function is primarily a manifestation of system properties. Thus, the emergence of the property of adaptability in the near future of cadastral systems will contribute to the emergence and development of a bundle of functions of the state's cadastral system aimed at adapting this system to the environment of its functioning.

Adaptability as a promising property of the government cadastral system is expressed in the ability of the system to purposefully adaptive behaviour in complex environments. To develop this property of cadastral system it is necessary to understand the term "adaptation" as in cybernetics, where adaptation is a process of accumulation and use of information in the system aimed at achieving a certain, usually optimal in some sense, state or dynamics (behaviour) of the system under the initial uncertainty and changing external conditions, changes in the environment.

The need for adaptability is due to the ongoing digital transformation of land-use systems, which leads to the increasing complexity of national cadastral systems. All this contributes to their increasing role in providing the land management system with sufficient and reliable information.

The essence of digital transformation in the Russian land use system is the digitalisation of the acquisition, accumulation and further use of information on land use as a system, including the digitalisation of production processes that take place in it (especially in agrarian land use) and the digitalisation of state land management processes.

The digital transformation in land use is dictated by the following challenges facing the global land use system: rapid population growth, rapid urbanisation, the emergence of a global food and environmental problem, flat economic development resulting from spatial evolution, the emergence of the informal economy in the form of diffuse penetration of foreign capital into the lands of border areas in states.

It should be noted that certain mechanisms inherent in adaptation (in terms of cybernetics) as pilot projects have already begun to be implemented in the Russian national cadastral system: consolidation of disparate stored data into a unified information system of storage and interpretation, increase of digital services of the cadastral agency, introduction of blockchain technologies for real estate transactions and artificial intelligence in conducting primary legal examination, matching data from documents with the deed In terms of organisation, the above changes and other changes that will be necessary to meet the challenges of our time will be summarised in the Concept of digital transformation of the Federal Service for State Registration, Cadastre and Cartography in 2021 – 2023 [8].

4. Conclusion
The following conclusions were drawn as the conclusion of this study:

1. From the point of view of systemic scientific ideas, the development of the state cadastral system follows a logistic curve with a breakdown into stages. Each stage is characterised by separate stages of development of cadastral system functions.

2. Adaptability as a prospective property of the State inventory system is expressed in the ability of the system to purposefully adaptive behaviour in complex environments. The need for this new property is driven by the ongoing digital transformation of land-use systems as a response to the challenges facing the global land-use system.

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