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System of designing livestock small-volumetric cooperative buildings

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Abstract. It was determined that the design system for livestock small-scale cooperative buildings is formed under the influence of a significant number of different factors, since it is necessary to take into account the adaptation of buildings to the environment and the peculiarities of the organization of their internal environment. In addition, livestock buildings have differences depending on functional characteristics, design solutions, used building materials, etc. An innovative solution that takes into account the variety of characteristics of the building's internal environment as much as possible is livestock breeding low-volume cooperated buildings. These buildings have the specifics of functioning in the external environment, so the formation of an appropriate design system is necessary. For the effective functioning of such a system, its components consolidated on the basis of modeling. The design system model for livestock cooperative small buildings was developed taking into account the multifactorial influence of the external and internal environment of buildings, as well as design conditions, and the main components of the system were determined, the relationships between them and their characteristics. The proposed model of a design system for livestock low-volume cooperated buildings shows the interdependence of its components and describes the parameters of their interaction.

1. Introduction

The design system for livestock buildings and structures is an important and significant task. When developing projects of cooperated and blocked buildings and premises, it is necessary to be guided by current building standards, technological design standards, as well as general and functional technological requirements, including: creating optimal conditions for introducing a unified progressive technology in livestock buildings, organization of production and material incentives labor; increasing the level of mechanization of production processes; selection of machinery and equipment, taking into account the overall dimensions of buildings designed and reconstructed; cooperation and blocking of production and auxiliary premises, linked to the general technological scheme of the enterprise; selection of space-planning and structural solutions of buildings for animals using the minimum number of standardized sizes of structures and products from both local materials and industrial ones; the implementation of thermal engineering calculations of enclosing structures, taking into account the regulatory parameters of the microclimate [1]. Since the general design system for livestock small-scale cooperative and blocked buildings consists of separate components aimed at creating organizational and technological unity, it is necessary to study modern aspects of design management with the development of an appropriate model of the design system, as well as to consider the methodology for assessing its components.

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2. Main material and results

Studies by Leonardo Conti, Matteo Barbari and Massimo Monti relate to the design of high-resilience livestock buildings. The authors propose innovative construction solutions that have the characteristics of low environmental impact and high economic competitiveness [2]. According to Inar Usta, Ayşe Arıcı, Ahmet Evci, Engin Kepenek, projects built in rural areas should be integrated with the natural environment. At the same time, it is necessary to use local traditional structures that can be easily made locally from renewable natural materials [3].

Any project that leads to changes in the development can potentially lead to a change in the landscape, which can affect the need to change the project. P. Tassinari, D. Torreggiani, G. Paolinelli and S. Benni believe that when designing buildings, it is necessary to first assess the impact of a building project on landscape changes. The quality of the landscape should be taken into account at several stages and levels of the development design process. The authors propose a conceptual model of the relationship between landscape changes, land planning, regulations, and building design. They consider the strengths and weaknesses of these relations, describe the existing methodological approaches to their assessment [4]. Hernández, J., L. García and F. Ayuga analyzed the location of rural structures. The variables of planning (physical, social, economic, legal) and the visual impact of buildings on the landscape were studied. The authors proposed the use of geographic information systems (GIS) to improve the integration of rural buildings in the area. GIS are excellent tools for landscape modeling in building design [5].

Investigations of the main relationships between livestock farms and their environs have been carried out. The study revealed that in countries with a high population density, livestock farms did not adapt well to landscapes. However, modern and well-managed farms improve the visual appeal of landscapes. Therefore, in order to improve the visual quality of rural landscapes that surround livestock farms, land should be allocated for the construction of new livestock farms in rural landscapes without charging for environmental problems [6]. Researchers Lim Yinghui Astee, Dr. Nirmal T. Kishnani draws attention to the need to take into account the capabilities of existing buildings when designing agricultural facilities. They propose the creation of integrated agriculture using roofs for sustainable food production [7]. Pietro Picuno explored the possibilities of using traditional materials in agricultural buildings for the rural environment. One of the most interesting traditional building materials is sun-dried earthen brick made from clay soil (“adobe”), which is often improved by adding fibers to control cracking during drying in the sun [8].

Olufolahan Oduyemi, Michael Okoroh conducted a study of building information modeling that improves their design. Modeling can bring significant benefits in terms of design and environmental assessment of buildings [9].

Thus, the design system of agricultural buildings is formed under the influence of many factors, since it is necessary to take into account the adaptation of the building to the environment and the features of the organization of the internal environment of the building. In addition, agricultural buildings have differences, depending on functional characteristics, design solutions, used building materials, etc. An innovative solution that maximally takes into account the variety of characteristics of the building’s internal environment is livestock breeding low-volume cooperated buildings. These buildings have the specifics of functioning in the external environment, so the formation of an appropriate design system is necessary.

Small livestock breeding cooperative buildings are part of a small agricultural enterprise – an agricultural production facility for growing, storing and processing certain types of agricultural products, as well as for keeping a limited number of farm animals and poultry, often with an incomplete composition of main and auxiliary buildings and structures, which can be built in various design solutions using single or disparate methods in mechanization. Small agricultural enterprises and peasant (farmer) farms should be located in the production zones of rural settlements or on farmlands in accordance with the approved district planning project, the planning and development of production zones of rural settlements based on technical and economic calculations. The placement of small agricultural enterprises and peasant (farmer) farms, buildings and structures is not allowed:

on the territory of mineral deposits without coordination with the bodies of the State Mining Supervision; in areas of mudflows, avalanches and landslides; on the lands of green zones of cities, including the lands of urban forests; on land contaminated with organic and radioactive substances before the expiration of the period established by the sanitary-epidemiological and veterinary services; on the lands of reserves, sanctuaries; in the protection zones of historical and cultural monuments; in areas of peat; in the first and second zones of the sanitary protection zone of centralized water supply sources; in the first and second zones of the districts of sanitary protection of resorts; in places where there were previously manure storages, cattle cemeteries; in territories unreliable to infectious diseases. The selection of land for the placement and construction of small agricultural enterprises and peasant (farmer) farms is carried out taking into account the territorial development of settlements, their transport routes.

The basis of the architectural and planning organization of any enterprise in Ukraine is a general plan that is developed for agricultural enterprises taking into account the requirements of state building standards [10, 11, 12]. When developing schemes of master plans for industrial zones of the agro-industrial complex and general plans of agricultural enterprises, they go beyond the requirements of technology, the rational placement of buildings and structures, and the provision of sanitary-hygienic and veterinary requirements. At the same time, engineering, architectural, artistic and economic factors are taken into account. Master plans for industrial zones of rural settlements with the placement of small agricultural enterprises and peasant (farmer) farms are developed for a period of 20-25 years, unless otherwise specified in the design assignment.

In the development of master plans for the construction of farms should include:

– division of farms into zones: residential, industrial and service areas (figure 1);
– planning and construction taking into account the distributed maintenance of groups of animals and birds;
– distribution of transport serving farms on the external and internal;
– equipping of barriers at the entrance to the territory, etc.

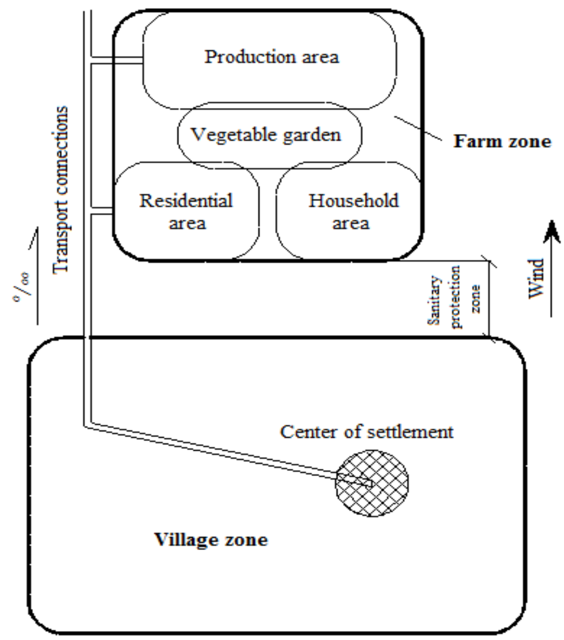

Figure 1. General layout of the farm relative to the settlement area.

When choosing a farm development plan, it is recommended to take into account the problems associated with the profitability of the farm, namely: to create a farm is desirable with the production of various types of products such as meat, milk, fur, etc.; to try to create a closed cycle of production (products must be processed in the farm with subsequent sale in finished form, processing of products can be organized on a cross-farm basis); anticipate the project and use equipment and appliances that are simple and reliable in operation; when planning and building farms, it is necessary to provide for the possibility of providing maximum comfort and convenience of residence for members of the farm. When cooperating in low-volume livestock buildings, one should strive for maximum technical and economic effect, including by significantly reducing the length of the heating lines, reducing the cost of metal pipes and insulating materials, reducing the cost of laying and operating; reduction of heat losses of cooperative and blocked buildings and more. The system of designing livestock small-scale cooperative buildings should take into account the peculiarities of their operation, is based on the general provisions of agricultural production, accurate calculations of the natural and economic features of a particular farm and prospects for its development.

Livestock farming is formed on the basis of a set of factors and planning decisions. Factors influencing the formation of a cooperative livestock building include: natural and climatic (parameters of the external climate, terrain), socio-economic (the need for types of agricultural products, requirements for its quality; the state of development of the region, labor and natural resources; staffing), functional and technological (production technology, norms of planning elements, purpose and specialization of the enterprise, production capacity, systems and methods of keeping animals), technical (constructive design). solutions, building structures and materials, engineering equipment), sanitary and hygienic (microclimate, influence of unfavorable factors on working conditions, influence of unfavorable factors on constructions of buildings), town planning (district planning, requirements to the territory and its choice, zoning of the territory of the enterprise), environmental (presence of harmfulness, reclamation, protection against harmfulness), architectural and artistic (space-planning solution, spatial solution, color solution). The transport links of the rural area with the production area of rural settlements and with individual small agricultural enterprises and peasant (farm) farms should be provided in accordance with the scheme of district planning, development of inland farms, inland agricultural land use and the master plan of rural settlement. The area for the placement of farms and the construction of buildings and structures of agricultural use must satisfy hygienic, zoo-veterinary, engineering, construction and economic requirements. Industrial aesthetics also play a significant role, with the emotional impact of various environmental factors on the worker, facilitating or hindering him from dealing with tools and objects of work.

The formation of the design system of livestock small-scale cooperative buildings is characterized by multifactoriality, which determines the need for modeling. When creating a model system of designing livestock small-scale cooperative buildings, a set of logical relationships was used. This mapping combines the elements of the design system under study into similar groups of model elements. In other words, a model is a conditional image of a design system designed to simplify its study. The study of such a model gives new knowledge about this system of designing livestock small-scale cooperative buildings. By definition, the model is abstract. It identifies the most significant factors, determines the patterns of operation of the studied design system and abstracts from other factors, which, although having little impact, but in the aggregate can determine the behavior of the model. All factors not considered in the model are assumed to have a negligible effect on the design system in the investigated aspect. The composition of the factors considered in the model and its structure can be refined based on the knowledge gained as a result of deepening the study of the design system. Many years of global experience have proven that models are capable of being a powerful tool for scientific analysis and forecasting, for producing outputs that are adequate to the object being studied.

In forming the model, all the interrelations of the design system of livestock small-scale cooperative buildings can be quantified, which allows to obtain objective data on the state of operation of this design system. The interpretation of the simulation results aims at moving from the information obtained from the model study to the description of the components and interrelations of the design system of livestock small-scale cooperative buildings. Based on the analysis of simulation

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results, decisions are made regarding the conditions in which the control system will function most effectively.

The model system of designing livestock small-scale cooperative buildings is considered as a set of enlarged components, which are essential for the existence and functioning of the system under study. The unity of the elements of the system, the connections and the interactions between them form the integrity of the system and the components - the structure.

As a result of the analysis, the components were identified and the interconnections of the system of designing livestock small-scale cooperative buildings were identified. Enlargement of the components of this system are six subsystems: socio-economic, subsystem "block of buildings", territory, subsystem of design solutions, regulatory documents. The socio-economic subsystem is characterized by the level of economic development, social demand for agricultural production and the availability of labor resources. The second subsystem includes cattle-breeding small-scale cooperative buildings, which are characterized by functional-territorial structure and three-dimensional planning organization. The third subsystem includes the territories, which are characterized by the area, the relief, the distance from the cattle-less cooperative buildings, the quality of the soil. The fourth subsystem includes the master plans. The fifth subsystem is characterized by the development of design solutions for livestock small-scale cooperative buildings and the development of appropriate master plans. The sixth subsystem is characterized by regulatory documents. There are interconnections between subsystems.

Based on this approach, a graph model was formed (figure 2). The model presented has edges (links) and vertices (corresponding subsystems), which are combined into a single system (S). Each component of the system corresponds to a specific vertex of the graph model. Cattle-less cooperative buildings correspond to the top S_b, territories – S_r, socio-economic subsystem – S_c, design decision – S_p, master plans – S_g, regulatory documents before designing – S_h. There are interconnections between the subsystems, which are characterized by edges of the graph model $(S_p – S_h)$, $(S_p – S_b)$, $(S_p – S_r)$, $(S_p – S_g)$, $(S_p – S_c)$, $(S_b – S_g)$, $(S_b – S_g)$, $(S_b – S_c)$. The edges of the graph-model of the design system of livestock small-scale cooperative buildings $(S_p – S_h)$, $(S_p – S_b)$, $(S_p – S_r)$, $(S_p – S_g)$, $(S_p – S_c)$ – characterize the connections between design decisions and regulatory documents to the design, livestock small-scale cooperative buildings, territories, master plan, socio-economic subsystem. Edge $(S_b – S_g)$ – characterizes the connection between low-volume cooperative buildings and the master plan, $(S_r – S_g)$ – connects between territories and the master plan, $(S_b – S_c)$ – connection between livestock low-volume cooperatives buildings and the socio-economic subsystem. Together, the vertices and edges form a structure that graphically represents the model of the design system of livestock small-scale cooperative buildings (figure 2).

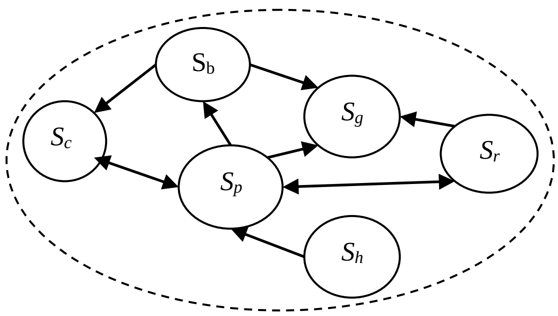

Figure 2. Graphic model of the design of livestock cooperative buildings.

As a result of the study of model relationships, single bonds were identified that affect only one component. On this basis, the components of the subsystems were consolidated. After such changes, the system is represented by such components as socio-economic subsystem, design decisions, livestock cooperative buildings, territory (figure 3).

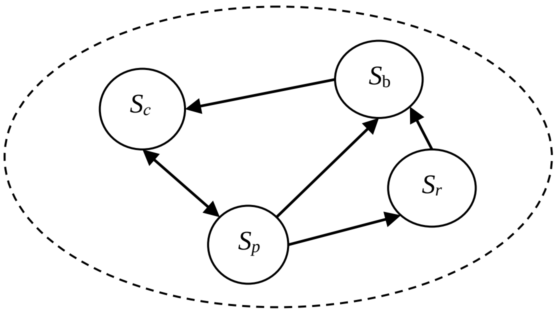

Figure 3. Graph-model of system of design of livestock cooperative buildings after enlargement.

The description of the graph-model of the system of designing livestock cooperative buildings is proposed based on the structural-functional approach [13]. To this end, a study of the design system of livestock cooperative buildings was carried out and determined:

– the primary element of the system $(S_i \in S), i = p,b,c,r;$

– compiled a list of subsystems and elements based on structural decomposition method;

– existing relationships are defined in the system;

– many actions have been formed to influence the processes of the system (Y_o);

–the mechanism for implementing the goals of the system was defined:

$$(F \times Y_0 \times G \to E_0). \tag{1}$$

– the mechanism of the system's functioning was defined:

$$(Y_0 \to E_0). \tag{2}$$

As a result, a common model of the system of designing livestock cooperative buildings was obtained. Based on this approach, the description of the system (S) of the graph model looks like:

$$S = \langle Y_o, E_o, F, G, R \rangle, \tag{3}$$

where Y_o – the cost of resources for the design of livestock cooperative buildings; E_o – efficiency of the system of designing livestock cooperative buildings; F – macro function of the system; G – system structure; R – emergence relation.

Emergence – the presence in the system of integrity properties (emergent properties), that is, those properties that are not characteristic of its elements and are one of the manifestations of the dialectical principle of the transition of quantity into quality. The emergence of a system is certain qualities of a given system, each of which is not peculiar to its elements, but arises due to the combination of these elements into a single, integral system. The macro-function of the system is a quantitative expression of the main goal of the system, depending on the cost of the resources that it consumes. The choice of macro-function ensures the achievement of economic efficiency of the design system of livestock cooperative buildings. It is associated with solving the problems facing the system. Only with certain resources (U_o) is it possible to ensure the effectiveness (E_o) of the system. The mathematical expression of the macro function is:

$$F : U_0 \to E_0. \tag{4}$$

Achieving the main goal of the system is possible when implementing the macro function (F), which must correspond to a certain structure of the system (G) and its integrity (R):

$$R : F \to G. \tag{5}$$

The emergence ratio (*R*) defines the correspondence between the macro-function of the system (*F*) and the structure (*G*), that it implements. The emergence ratio (*R*) changes every time when the correspondence between the macro function and the structure is broken.

The dependency is defined as follows:

$$G = \left\langle \{S_c, S_p, S_b, S_r\}, (S_c, S_p), (S_p, S_b), (S_p, S_r), (S_b, S_c), (S_p, S_c), (S_r, S_b) \right\rangle, \tag{6}$$

where $\{S_c, S_p, S_b, S_r\}$ – vertices of the graph – model; *c, p, b, r* – indices that characterize the components of the system: respectively socio-economic subsystem, design solutions, livestock cooperative buildings, territory; $(S_c - S_p)$, $(S_p - S_b)$, $(S_p - S_r)$, $(S_b - S_c)$, $(S_p - S_c)$, $(S_r - S_b)$ – many connections between the vertices of the graph – model.

The components of the graph – model (figure 2) are represented by the functions:

$$f_1 : S_c \to \{L_c, U_c\}. \tag{7}$$

$$f_2 : S_b \to \{C_b, M_b, t_b, R_b, E_b\}. \tag{8}$$

$$f_3 : S_r \to \{G_r, A_r, K_r, E_r\}. \tag{9}$$

$$f_4 : S_p \to \{H_p, D_r\}. \tag{10}$$

$$f_5 : (S_r - S_b) \to \{Y_{r-b}, E_{r-b}\}. \tag{11}$$

$$f_6 : (S_c - S_p) \to \{L_{c-p}\}. \tag{12}$$

$$f_7 : (S_p - S_r) \to \{V_{p-r}\}. \tag{13}$$

$$f_8 : (S_p - S_b) \to \{E_{p-b}, N_{p-b}\}. \tag{14}$$

$$f_9 : (S_p - S_c) \to \{E_{p-c}\}. \tag{15}$$

$$f_{10} : (S_b - S_c) \to \{E_{b-c}\}. \tag{16}$$

The first four functions characterize the components of the system, the remaining functions– the relationships between them.

The socio-economic subsystem is the main source of financing for the design and construction of cooperative livestock buildings. It has a certain amount of financial resources (L_c), that can be invested in design and construction on a profit (U_c). Construction objects are characterized by the cost of construction (C_b), the cost of logistics (M_b), the duration of construction (t_b), financial risks (R_b). At the same time, logistics is focused on a network of industrial and construction industry enterprises, transport and energy organizations, design and other institutions. It is aimed at providing the construction of livestock small cooperative buildings with the necessary material and technical resources.

Territory is a necessary warehouse system and a project for the creation of cooperative business, so it is so easy to organize for the organization of functional functions. Vaughn is characterized by natural-geographical resources (G_r), natural-anthropogenic resources (A_r), relief (K_r) and effective territory of the territory (E_r).

The design process is characterized by the design work capacity (H_p) and work capacity (D_p).

The relationship between construction sites and territories is characterized by transportation costs ($Y_{r\text{-}b}$) and logistics efficiency ($E_{r\text{-}b}$). The location of the territories affects the choice of construction site and the formation of master plans.

The following function characterizes the relationship between the socio-economic subsystem and design decisions. This characteristic is the amount of financial resources ($L_{c\text{-}p}$), that are invested in design and construction. The relationship of design decisions and territories is characterized by the cost of landscaping, which will be used in the operation of livestock cooperative buildings ($V_{p\text{-}r}$). The relationship between design decisions and livestock building cooperative buildings is characterized by construction efficiency (E_{p-b}) and construction payback (N_{p-b}). The two final functions are characterized by the efficiency of design decisions (E_{p-c}) and the efficiency of the functioning of livestock cooperative buildings (E_{b-c}). The interaction of components, as a holistic system, ensures their dynamic development. The proposed model of the project system for the livestock breeding of small-sized cooperated buildings shows the interdependence of its components and describes the parameters of their interaction.

Thus, the use of simulation made it possible to identify the most important relationships between the components of the design system of livestock low-volume cooperative buildings and to characterize the dependencies between the parameters of these subsystems.

3. Conclusion

Livestock cooperative small buildings are the part of a small agricultural enterprise for the cultivation, storage and processing of certain types of agricultural products, as well as for the maintenance of a limited number of animals and poultry. They should be located in the production zones of rural settlements or on agricultural land in accordance with the approved master plans, which take into account the division of the territory into zones (residential, industrial, service), the maintenance of groups of animals and birds, transport services for livestock buildings.

It was established that the design system of livestock cooperative small buildings is formed under the influence of a significant number of different factors.

It was determined that when designing livestock cooperative small buildings, it is necessary to take into account the influence of the environment, especially the formation of the internal environment, the organization of construction. At the same time, livestock buildings differ in functional characteristics, constructive solutions, used building materials, etc. In connection with this, an innovative solution is needed that takes into account the multi-factorial formation of the design system for these buildings. Such a solution is to use modeling. For this purpose, the components of the design system were identified. This is a socio-economic subsystem, a “block of buildings”, a territory, regulatory documents and a subsystem of design decisions. The relationships between the components are also identified.

The authors developed a graph is a model of the design system for livestock cooperative small buildings, which shows the interdependence and interaction of its components. When developing the model, the functions that characterize the components of the system and the relationships between them were determined.

The developed model makes it possible to quantify the components and interconnections of the design system of livestock cooperative small buildings. This approach allows you to obtain objective data about the state of operation of this system. Organization of effective interaction of components, as an integrated design system, ensures their dynamic development.

Thus, the use of modeling made it possible to form a design system for livestock cooperative small buildings, which takes into account the multifactorial influence of the external environment, the internal environment and the organization of design.

Further research should be aimed at organizing an assessment of the quality of design decisions in the design system of livestock cooperative small buildings.

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