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Abstract. The work is devoted to the problem of determination of effective architectural, structural, organizational and technological solutions in the multifunctional civil construction. Methods for determining effective solutions of civil construction were proposed. An efficient architectural and planning solutions of childcare centers of integrated-attached type were developed. There were presented the results of study of the effect of depth, angle of inclination of damages, relative eccentricity on bearing capacity of brick structures. The optimization algorithm and efficient solutions were found in the civil construction under organizational and financial constraints. Seven walling innovative solutions with improved thermal characteristics were proposed. There were found effective construction solutions of walling structures erection under the influence of organizational and technological factors.

Keywords: optimization, civil construction, childcare centers of integrated-attached type, architectural and organizational planning, brick structures, walling structures, energy efficiency, organizational and financial constraints, organizational and technological solutions.

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CONTENTS

INTRODUCTION

The main problem to be solved. The work is devoted to the problem of determining the effective architectural, structural, organizational and technological solutions of the multifunctional civil construction.

Topic relevance. Currently, civil engineering is the most common in Ukraine. According to the Office of Statistics of Ukraine for the period 2010-2018 years, its volume has increased by 3.4 times (from 19 659.1 million UAN to 66 791.6 million UAN). Moreover, the civil construction demonstrates higher growth rate compared with the volume of industrial construction, which has increased for the same period by 3.2 times (23 259.0 million UAN to 74 421.5 million UAN). Multifunctional civil construction, that combine several functions, is highly relevant. Such buildings include both sections of commercial, educational and residential purposes. Not enough research were devoted to find effective construction solutions of such buildings and their parts. The effectiveness of methods of such solutions can be grounded on:

- First, the complexity and interdependence of the parts of such buildings require the comprehensive solution of this problem: from an architectural, structural, organizational and technological points of view.
- Second, the optimization of construction solutions in terms of versatility of buildings under consideration.

It is possible by systematic optimizing solution of the task: increase the economic efficiency of multifunctional civil construction; reduce the cost of construction and operation; increase technical efficiency.

Thus, it can be concluded that the task of developing methods and search for effective solutions (architectural, structural, organizational and technological) in civil engineering is important.

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CHAPTER 1.

Denys Sayenko.

Rationalization of architectural and planning concepts: a study of childcare centers of integrated-attached type

Abstract. The research deals with optimization of architectural and planning concepts of childcare centers of integrated-attached type; has scientifically substantiated the new architectural object - architectural and planning organization of childcare centers of integrated-attached type as a system integrity, interacting with other educational establishments and social welfare institutions within the structure of residential areas; has analyzed the formation and historical development of the architectural and planning organization of childcare centers of integrated-attached type in the national design experience; has developed architectural and spatial development perspective concept within childcare centers of integrated-attached type under limited land and other material resources taking into account the basic general provisions of continuity; has defined the architectural and planning principles of childcare centers of integrated-attached type (accessibility, integration, cooperation, environmental friendliness, transformation). The author has improved: practical methods of architectural and planning organization of childcare centers of integrated-attached type, responsible for the implementation of the principles proposed in the research. The author has developed: recommendations as for the architectural, planning and functional organization of childcare centers of integrated-attached type; the author has determined the ways of their optimization and statutory regulation under compacted urban development, recommendations for functional and planning organization and improvement of the territories of childcare centers of integrated-attached type.

Key words: childcare center, integrated type, attached type, kindergarten.

Introduction. Childcare centers, as a material representation of educational and socio-pedagogical programs and requirements, are under the influence of changes taking place within socio-economic, demographic and cultural life of society. The dynamic nature of these processes necessitates periodic reorganization of the whole system of pre-school education, with its integral part to be the building of childcare centers. Today, Ukrainian society has again returned to the renewal of the design concepts of integrated-attached type of a childcare center, which turned out to be the most urgent in present changing structure of the city, residential area, neighborhood, quarter. It should be noted that last century our country had an experience in kindergartens integrated-attached designing to residential and public buildings (schools, administrations, enterprises cafes, etc.), but later this type of childcare centers was completely replaced by the design of independent kindergartens with large territories.

In the late 80’s - in the early 90’s of the XX century under difficult demographic situation, the occupancy level of childcare centers began to decrease, which resulted in reduction of the number of kindergartens and closure of some childcare centers. The early XXI century saw a certain rise in the economy of Ukraine, with higher attention of state bodies to children’s problems, financial and social stimulation of multi-child families, which, along with the relative stability in our country, led to an increase in the children birth rate and, accordingly, an increase in the demand for preschool childcare centers. During the last five years all Ukrainian cities have overstretched childcare centers, if at all. For example, Kyiv and Odesa have 60% of such kindergartens. Apart from the demographic fluctuations, the lack of childcare centers was the result of the growing urbanization processes, compacted urban environment with high-rise multi-apartment blocks and public buildings. This new high-rise constructing is characteristics of not only the outer peripheral areas of large cities, with their relative reserve of non-occupied territories to develop the necessary social and service infrastructure, but also of the central, historical districts with high-rise complexes being more prestigious and cost-effective for private investors. In the latter case, the design of kindergartens of integrated-attached type is the most appropriate way to address the issue of preschool education of new residents. Childcare centers of integrated-attached type in their own structure are universal buildings, which are easily adapted to the spatial arrangement of the building, so they can be used in multifunctional complexes.

The purpose of the research is to develop conceptual framework, principles and techniques of architectural and planning organization of childcare centers of integrated-attached type.

Objectives of the research:

- Analyze the problem of designing childcare centers.
- Analyze the general methodology of the research, to identify the factors influencing the development of architectural and planning organization of childcare centers of integrated-attached type.
- Rationale methodological principles of organization of functional and planning structure of childcare centers of integrated-attached type.
- Develop the principles and methods for blocking the childcare centers to residential buildings and public services institutions.
- Make proposals as for organizing the territory of the childcare center of integrated-attached type.
- Make proposals as for optimizing the architectural and planning structure of the childcare center of integrated-attached type.

The analysis of the problem of childcare center design.

Theoretical studies of childcare educational institutions network formation as an object of architectural and urban design are represented in numerous publications. We have analyzed domestic and foreign scientific researches, which partially considered the stages of educational branch objects formation, the role of educational institutions in the evolution of the national architectural and urban development activity. The above-mentioned researches deal with the definition of higher educational institutions network formation [1-3], the architectural and typological development of general education institutions and architectural and urban design features of schools, lyceums, secondary schools and vocational schools [4-41]. In order to identify the trends in the development of the architecture of childcare educational institutions, to define advanced directions for the development of educational institutions network we have analyzed the theoretical works dedicated to education development [16, 17].

The emergence and development of childcare centers in Ukraine was influenced by the socio-political activity of the society after the Second World War, which required higher public service in the development of urban settlements. The 60s of the XX century, connected with the democratization of public relations, the search for progressive forms of urban development, the development of mass typical construction, set the task of providing residential areas with objects of the social facilities, including childcare centers. At this time, H. O. Hradov's concept of multi-staged servicing system emerged, according to which all public services were divided into degrees (levels) depending on the frequency of use (daily, periodic and occasional) [18]. A housing group with daily maintenance childcare centers was identified as maximum close to the consumer and the primary element of service. Research of educational institutions architecture development in the Soviet period was carried out in a number of architectural and typological scientific works [3, 8, 19-20].

The problems of improving the childcare centers network were studied within the framework of zonal civil engineering construction R&D institution “KyivZNDIEP” scientific activity with the following proposals provided: in highly compacted residential complexes, it is recommended to exploit consolidated types of childcare centers with a significant economic effect owing to centralized economic processes and reduced land plots. It is proposed to create an interconnected system of educational institutions with separate center of pre-school education at the level of the housing complex. As a result of predicting the dynamics of new residential areas population age structure, it was established that after 35 years after commissioning the residential areas, sharp fluctuations gradually cease, the age structure of the population is stabilized with the percentage of children approaching the average urban indicator [23, 24].

Researches, conducted at “KyivZNDIEP” concerning placing childcare center within the structure of the residential complex, took into account a variety of factors ranging from sanitary, hygienic and architectural and constructive norms to the questioning of academic teachers, regarding the influence of the architectural environment on the educational process. These led to the conclusion that the nearest buildings and houses should be placed to the kindergartens with their sidewalls. In 1983 an advanced model of the typological and urban planning of preschool education system was developed within the framework of the childcare centers of integrated-attached type under high, medium and low housing compactness.

Problems, approaches, methods and techniques of designing childcare centers are represented in methodological and educational literature, in monographs by L. M. Kovalskyi, G. L. Kovalska, S. M. Linda, O. S. Sleptsov,

I. G. Osadchyi, B. S. Posatskyi, V. I. Proskuryakov, O. M. Yurchyshyn and others. [21, 22, 25-35]

The existing norms determine the size of land plots of independent childcare centers, which are calculated depending on the capacity of institutions. As for integrated-attached childcare centers, there are strict restrictions concerning the placement of such institutions in design and construction norms. In particular, the State Building Regulations B.2.2-4-97, clause 2.2 allow direct adjoining of general type childcare centers sections to the sidewalls of residential buildings without windows, to which the childcare center is attached. Clause 3.5. allows attachment of general type childcare centers with fire resistance not lower than II degree with a capacity of up to 160 places to the dumb sidewalls of residential buildings of the I-II degree of fire resistance, as well as placing in the lower floors of residential buildings the manager’s office, curriculum office, changerooms and toilets for the staff of the integrated-attached general type institutions with the capacity of up to 120 places with the same fire-resistance degree. In this case, childcare centers premises should be separated by fire partitions of type 1, slabs of type 3, with the exits, separated from the entrances to residential buildings. Table 1 of the State building regulations B.2.2-4-97 defines the areas of each functional zone of the land plots of kindergartens, suggests the area of passages, tracks, technical sites, etc. outside functional zones, which is 20% of the amount of functional zones [36, 37].

It should be noted that the aforementioned provisions considerably limit planning of childcare centers of integrated-attached type and require additional research and rationale.

Clause 6.1.5 of State building regulations 360.92** “Urban planning. Planning and Development of Urban and Rural Settlements” permits placing childcare centers in the form of: integrated premises for the groups of short-period (up to 4 hours) staying for preschool-aged children on the ground floors of residential buildings; integrated childcare centers with a total capacity of up to 80 places (2-4 groups) on the ground or the 1st floors of residential buildings; integrated-attached childcare centers with the capacity of up to 120 places (up to 6 groups) on the ground or the 1st floors of residential buildings; attached childcare centers with capacity up to 160 places (up to 8 groups) to the dumb sidewalls of residential buildings [38].

The normative act states that the land plot of a childcare center of integrated-attached or attached type to a residential building shall be separated by the fence and planted land from the adjoining territory of a residential building.

Summing up the analysis carried out in the chapter concerning scientific research in the field of designing educational institutions and architectural and planning organization of childcare centers of integrated-attached type in particular, it should be noted that numerous existing scientific works do not reveal the above-mentioned issue. In this regard, it is still urgent to study childcare centers of integrated-attached type, to improve the outdated planning schemes of this type, to develop and implement new, modern childcare centers adapted to changing requirements of the modern town-planning concept. Owing to existing R&D innovations, we have detected various variants of distribution of the total number of places in a childcare center.

Analysis of general research methodology, factors influencing the development of architectural and planning organization of childcare centers of integrated-attached type.

Research of the problem of complex, and, in particular, functional and planning organization of childcare centers, offers to place the childcare centers in a compacted urban structure, taking into account the individual urban conditions of a certain territory, should be based on the system of design approach. The above-mentioned approach creates conditions for childcare centers of integrated-attached type to be regarded as a component of general pre-school education system, which in turn helps to identify the diversity of relationships between its individual elements and the further ways of improving childcare centers.

The rapid development of urban processes in Ukraine, modern trends of pre-school education development, technical and information technologies require the formation of qualitatively new conditions for children's staying in kindergartens. It should be noted that this area has already undergone some positive changes in legislative and regulatory acts of design and construction industry, but these innovations need to be clarified and extended. Thus, in order to make proposals for the architectural and planning organization of childcare centers of integrated-attached type, we have conducted the analysis of domestic legislative and normative acts, theoretical and practical foreign and domestic experience in designing kindergartens, with further identification and analysis of applied scientific and design methods and means of childcare centers realization.

According to the provisions of the Law of Ukraine "On Pre-School Education", pre-school education is defined as a compulsory primary component of the system of continuous education in Ukraine; pre-school education is a holistic process aimed at: ensuring the balanced development of a preschool-aged child in accordance with his/her inclinations, affections, abilities, individual, mental and physical characteristics, cultural needs; forming moral norms of a preschool-aged child with further acquisition of life social experience. The *pre-school education concept*, according to the Law, consists and includes: pre-school education institutions of any subordination, ownership types and forms; scientific and methodological institutions;

educational authorities; family education and upbringing. The *pre-school education principles* include: accessibility of educational services provided by the pre-school education system; equal conditions to exercise inclinations, affections, abilities, talents, all-round development of each child; integration of development, education, training and rehabilitation of children; integration of educational influences of the family and pre-school education institution; continuity and perspective between pre-school and primary general education; secular nature of pre-school education in state and communal institutions of pre-school education; person-centered approach child’s personality development; democratization and humanization of the pedagogical process; compliance of the content, level and extent of pre-school education with the peculiarities of a preschool-aged child development and health [39].

The Law of Ukraine “On Pre-school Education” determines the *target of pre-school education* as preserving and strengthening the physical, mental and spiritual health of a child; raising children’s love for Ukraine, respect for the family, folk traditions and customs, official language, regional or minority languages and mother tongue, national values of the Ukrainian people, as well as the values of other nations and peoples, conscious attitude towards oneself and the environment; forming child’s personality, developing his/her creative abilities, acquiring social experience; carrying out the requirements of the Basic component of pre-school education, ensuring social adaptation and readiness to continue education; social-pedagogical patronage of the family [39].

The methodology of research helps to identify and assess the influence of pedagogical, social, demographic, architectural and urban conditions and factors on forming the structure of childcare centers of integrated-attached type, as well as to identify and characterize the methodological bases of designing and organizing the functional and planning structure of kindergartens in the urban environment of the specified type of organization (Fig. 2). Using the method of on-site investigation, statistical analysis, generalization of reported, informational and electronic sources, the author has systematized data on the number, peculiarities of location, functional composition and interconnection of premises of childcare centers with the identification of regional architectural and urban-specific features and perspective potentials for further design and construction under modern conditions of Ukraine.

Rationale of methodological principles of functional and planning structure of childcare centers of integrated-attached type.

Childcare centers are distinguished by the *purpose*:

- General type ones - for children with normal mental and physical development.
- Specialized type ones of compensating type - for children with birth and development defects (blind, deaf, mental defectives).
- Sanatory type ones - for children with reduced health; in areas (artistic-aesthetic, intellectual, physical development, etc.).
- Combined type ones - combination of groups of general and specialized types.

According to *age groups* childcare centers are divided into:

- nurseries for children under 3 years of age;
- kindergartens for children from 3 to 6 years of age;
- day care centers for children of 6 years of age.

Groups in Ukrainian kindergartens are traditionally formed according to the age of children. According to the provisions of State building regulations V.2.2-4: 2018, exceptionally, it is allowed to organize multi-age groups for children from 3 to 6 years of age for compact forms of childcare centers.

According to the *nature and time of exploitation* childcare centers are divided into year round and seasonal, as well as:

- short-term staying ones for a child to stay up to 4 hours;
- daily ones for a child to stay from 9 to 14 hours;
- overnight or weekly ones, where children stay six days a week for 24 hours;
- mixed type ones.

According to the *capacity*, childcare centers are divided into the following types:

- Centers with very small capacity (1 group, up to 15 children).
- Centers with small capacity (1 - 4 groups, with the total number of children from 20 to 80 people).
- Centers with average capacity (5 – 7 groups, with a total number of children from 100 to 140 people).
- Centers with large capacity (8 – 12 groups, with a total number of children from 160 to 240 people).
- Kindergartens with a capacity of more than 12 groups (240 children) are classified as complexes.

The capacity of nurseries, kindergartens and day care centers should not exceed 300 places (16 groups), baby nurseries and orphanages should have no more than 200 places. The capacity and structure of the complexes of childcare centers are determined by the design tasks. The number of places in each building with the premises of children's group centers should not exceed 300. Childcare centers with a capacity of up to 160 places can be combined with general educational institutions, thus creating educational complexes, and in urban-type settlements and villages childcare centers with capacity of up to 120 places can be combined with an apartment for personnel [136].

According to the *degree of integration into residential and public buildings*, childcare centers are divided into:

- Independent buildings.
- Childcare centers attached to residential or public buildings.
- Childcare centers integrated onto the ground floor level.

According to the legislation in force, it is allowed to place:

- integrated premises for groups of short-term staying (up to 4 hours) for preschool-aged children (nurseries - up to 3 years of age, kindergarten - 3 - 6 years of age (7 years of age) on the ground or the first floors in residential and public buildings;
- integrated childcare centers of general development (nurseries, day care centers, kindergartens) with the capacity up to 80 places (up to 4 groups) on the ground or the first floors in residential buildings;
- integrated-attached childcare centers of general development with the capacity of up to 120 places (up to 6 groups) on the ground or the first floors in residential buildings, taking into account fire regulations;
- attached childcare centers of general development with the capacity of up to 160 places (up to 8 groups) to the dumb sidewalls of residential buildings, taking into account fire regulations.

Day care complexes and educational complexes of “childcare center - general educational institution” type may consist of separately located or attached buildings. According to the provisions of State building regulations V.2.2-4: 2018, the *number of floors* of a childcare center should be not more than two. The exceptions are three-storied buildings of the childcare centers (but for special type institutions) that are allowed to be designed in the largest, large and big cities of the non-seismic regions of Ukraine in compliance with the relevant fire regulations, with fire alarm system, evacuation control.

The height of the stores above ground in childcare centers from the floor to the floor of the next stores should be not less than 3.3 m. The ground floors should have premises for children's groups (group and dwelling centers), halls for musical and sports classes, medical facilities, catering place. The second floor may have premises for senior groups, halls, game room, computer class, manager's office, curriculum office, assistant manager office, storerooms; basement may have a utility room, but for the manager's office and curriculum office, as well as laundry and kitchen, preparation shop, cooking battery wash, cooling chambers and storerooms; the cellar should have cooling chambers, vegetable storehouse, storerooms (but for storage of dry products), carpentry and fitting workshop, which ensures the functioning of the institution [136].

Industrial premises with a category of explosion-fire hazard higher than "B" are not allowed in childcare centers.

In developing space planning decisions of buildings of childcare centers for construction in various natural and climatic conditions, it is necessary to take into account the requirements of DSTU-N B V.1.1-27, State building regulations V.2.2-9, V.2.2-17. The space planning decision of the childcare centers buildings for construction in the I, II and III climatic regions should be taken, as a rule, as centralized or blocked. Houses in the steppe zones of these climatic regions may have a closed or semi-closed configuration, with a ventilated roof. For the areas above mining working, on collapsing soils and zones with seismicity of 7 points and higher block solutions should be taken providing the house breaking with contraction joints into modules. In the III, IV and V climatic regions with relief slope of more than 35% stepped and gallery solutions are allowed. Unheated passages between blocks are not allowed.

Childcare centers buildings should include external entrances to the premises for the children, as well as the central (service) entrance. The central entrance is allowed to be combined with the entrance to the premises for the children. External entrances to the premises for toddlers should be separate. It is allowed to design public entrances for not more than 2 nursery or 4 kindergarten groups in nurseries, kindergartens and day-care centers, for not more than 4 nursery groups in infant homes and for not more than 6 groups in orphanages. When dealing with external entrances it is allowed to design a hall-lobby for 2-4 groups with of 6 m² for each, a 4 m² chamber for one group. It is allowed to provide children's toilets with one W.C. bowl and one wash basin for 2-4 groups near lobbies and chambers. The external entrance to the lobby, hall or corridor of childcare centers should be designed with the entrance vestibule [40].

It is advisable to plan the structure of childcare centers buildings on the basis of *functionally integrated three main groups of premises*: children's centers; premises common for all children's groups (musical, PE, training classes and games); administrative and housekeeping premises (medical, service and household premises, catering place, laundry).

Developing principles and methods for childcare centers blocking to residential buildings and public services institutions.

In order to organize the optimal and effective, vulnerable to the demand and expectations of the community, childcare centers network, based on modern pedagogical concepts and approaches to the child's pre-school development, scientific research, as well as taking into account progressive foreign and national experience, the research proposes architectural and planning the principles for organizing childcare centers of integrated-attached type (Fig. 1, Fig. 2):

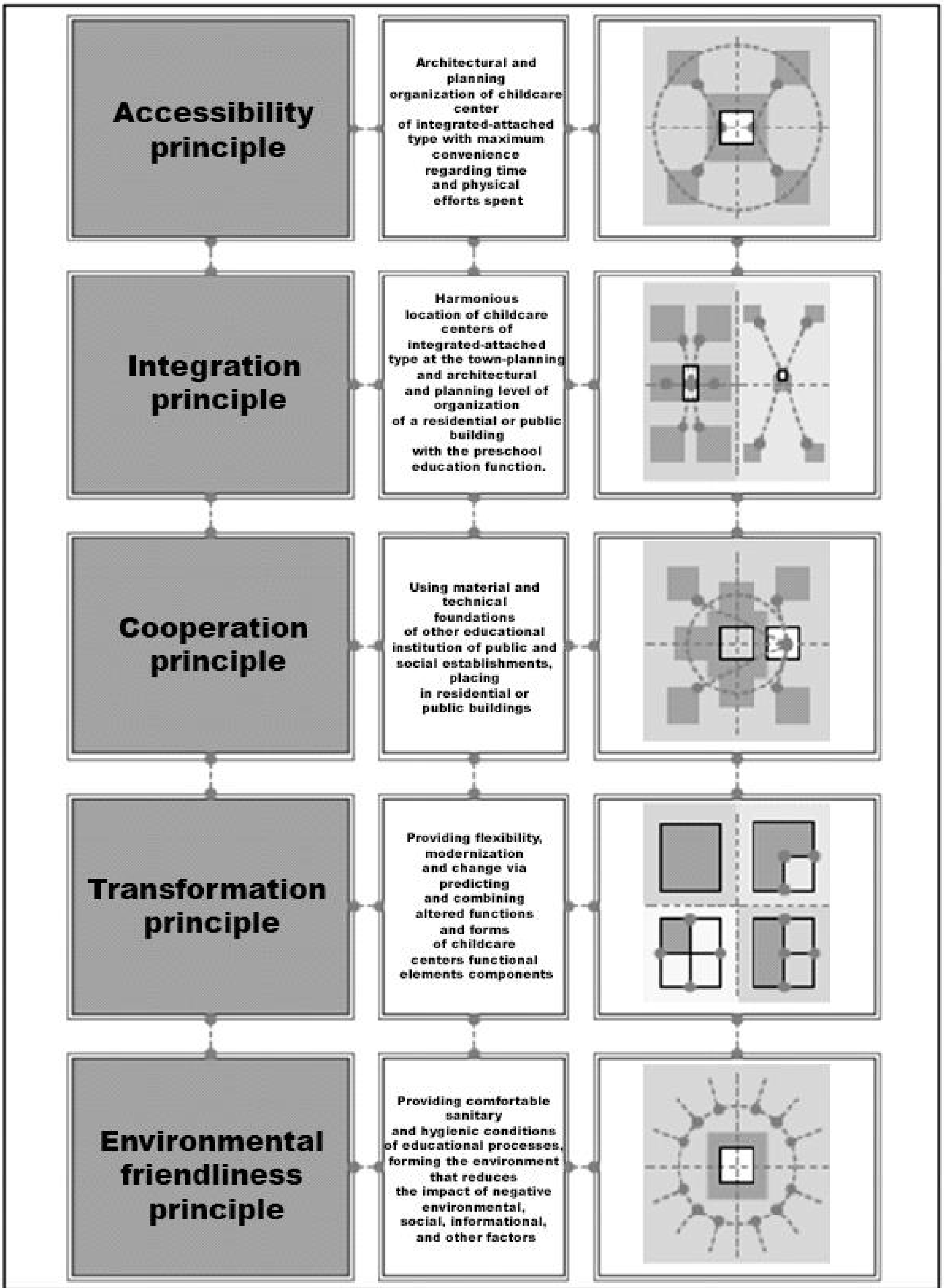

Figure 1. Principles of childcare centers blocking to residential buildings and public service institutions.

- accessibility principle;
- integration principle;
- cooperation principle;
- transformation principle;
- environmental friendliness principle.

The first principle – *the accessibility principle* – regards the architectural and planning organization of childcare centers of integrated-attached type in such a way that with the limited economic and territorial resources of urban planning, attending pre-school establishments would be maximum convenient regarding time and physical efforts spent. This principle is primarily governed by the desire to balance physiological stresses on children and their parents who naturally want to minimize the trajectory and routes to reach the nearest childcare center relatively the place of residence (or employment, daily public service).

The urgency of the principle of childcare centers accessibility is proved by the growing urbanization, constructing high-rise multi-apartment residential buildings without proper consideration of the capacity of the existing kindergartens network and their actual overloading in recent years, the insufficient level of engineering, in particular, transport infrastructure, etc. Within the urban planning aspect, this principle helps to implement and achieve compliance with normative radii of childcare centers services in Ukrainian cities, their reduction and optimization in residential areas of high-rise buildings.

The integration principle presupposes organic and harmonious location of childcare centers of integrated-attached type, both at the town-planning level of the urban settlement structure, and at the level of the architectural and planning organization of a building with the preschool education function.

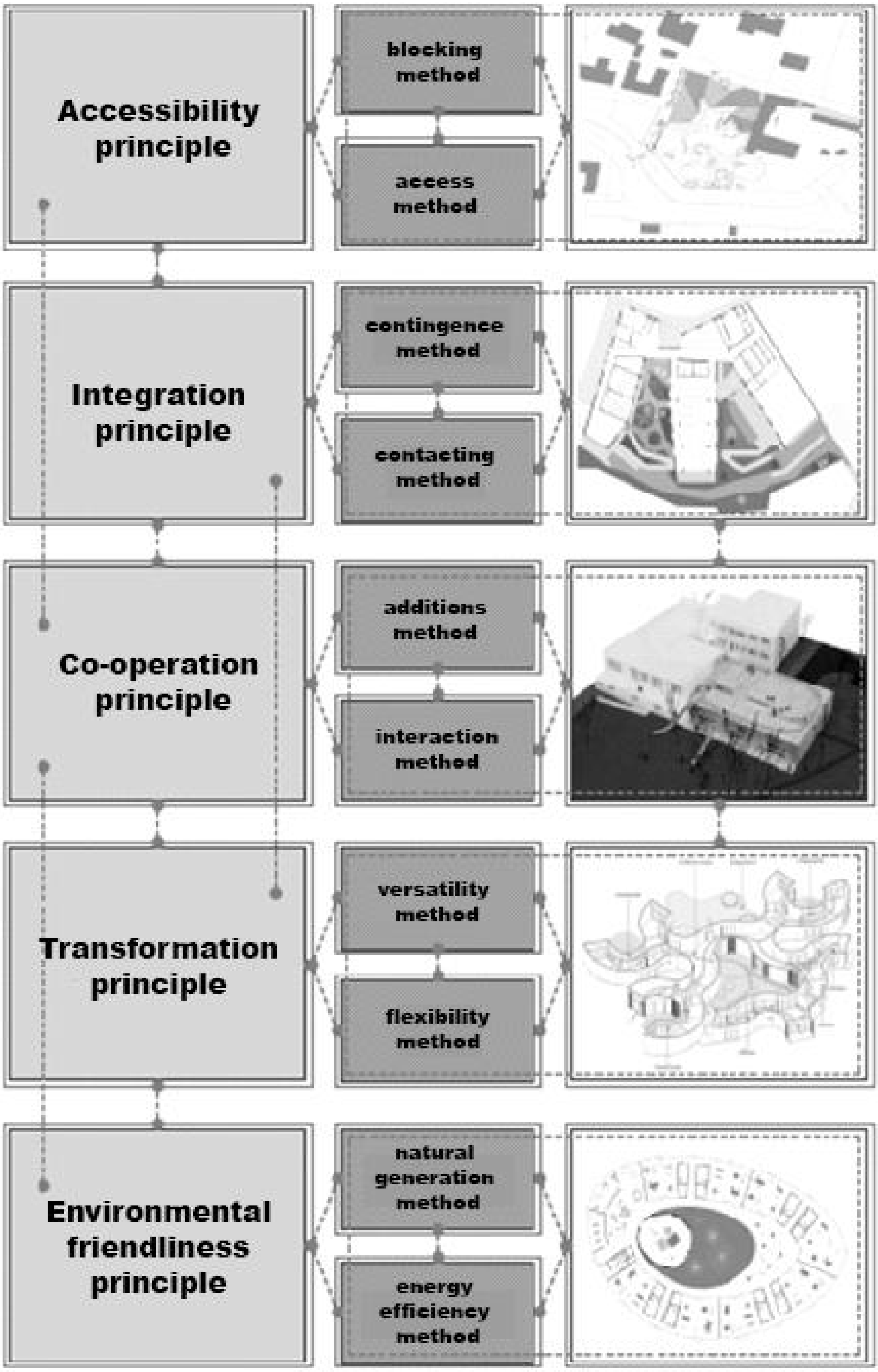

Figure 2. Principles and ways of childcare centers blocking to residential buildings and public service institutions.

According to this principle, pre-schools are integrated into the structure of residential or public groups of the urban environment (high-rise multi-apartment building or medium-size residential area, district or group quarters with low-rise buildings), taking into account the principles of their development and organization, population density and demand for pre-school education.

The next principle – *the cooperation principle* of childcare centers of integrated-attached type allows to significantly expand the network of pre-school educational institutions in urban environment. This becomes possible by providing pre-school education (partially or fully) on the material and technical foundations of other educational institutions (primary and secondary schools, educational complexes, extracurricular, private and commercial educational institutions, etc.), public and social institutions (sports, entertainment, healthcare, catering facilities, etc.), integrated into residential or public buildings.

Within the framework of the cooperation principle, childcare centers can be integrated or attached to residential and public buildings, integrating with a ‘donor” of prospective material and technical foundation, being a “connecting link”. This principle is based on cooperation of pre-school institution territory with the land plots of residential and public buildings and institutions, their real and more powerful material and technical foundation and infrastructure (sports facilities, canteens, medical institutions, conference rooms, laundry, etc.), allows to develop a childcare centers network under compactness and shortage of accessible and free urban areas, brings closer qualitative materially equipped pre-school education to the places of residence or employment of the citizens.

The transformation principle of architectural and planning organization of childcare centers of integrated-attached type allows to combine traditional methods of pre-school education with the new and innovative and progressive forms of education which are updated with the development of Ukrainian society. Today, new types of pre-school educational institutions must be consistent and connected with the implementation of requirements to provide qualitative and diverse education, introduction of modern pedagogical models and approaches in education, training, socialization of children along with the latest educational technologies.

The environmental friendliness principle of childcare centers of integrated-attached type provides comfortable sanitary and hygienic conditions of educational processes, forming educational environment that reduces the impact of negative environmental, social, informational, and other factors using architecture and urban planning. This principle becomes especially important in the architectural and planning organization of childcare centers in urban planning of large and the largest cities, in industrial regions of Ukraine with poor environmental conditions.

Proposals as for organization of childcare centers of integrated-attached type territory.

The territory of a childcare center is an important component and an integral part of the educational environment, intended to provide a comprehensive consolidation of different types of educational and healthcare processes, including group, PE and sports activities, educational and support exercises in the open air, general meetings and festive events, while creating comfortable conditions for children to relax during walks.

The quality of education, child safety and health depends to a certain extent on the rational and functional and planning concept of the territory of the childcare centers. The territory of the childcare centers of integrated-attached type requires the definition of a number of qualitative characteristics of the walkway, analysis of components that increase the attractiveness, educational potential of the architectural environment of pre-school education institution.

Independent buildings of childcare centers in a city structure, which are governed by the actual legislative documents [38, 40, 41], should be on the best land plots near residential or public buildings, far from transport highways, sources of pollution. The territory of pre-school institutions includes the following components: a walkway, footpaths, sidewalks, lawns and a gardening area, a public utility site with a passage.

It should be noted that traditionally the territories of existing childcare centers do not use the full potential of possible properties, are usually characterized by the uniformity of architectural-artistic and compositional solutions, standard equipment. This design approach, unfortunately, negatively affects the development of imagination and personal identification of a child, and does not contribute to diversity of cognitive, game and educational activities. Geometry of domestic children’s playgrounds in childcare institutions is mostly represented by rectangular or square shapes and sizes, covered with asphalt or sand.

The role of the playground in the development of children is beyond doubts. It should be noted that the landscape approach within children's playground of a pre-school institution allows to solve the following tasks: to create a variety of micro-landscapes, to enrich the landscape with flowers, decorative trees, bushes, etc., to plan altering open and cozy spaces, to take into account the scale according to a child’s size, perception and ergonomics that is 1:2, 1:4, 1:10, 1:20 of the adult’s size.

Taking into account that childcare centers of integrated-attached type are rather new phenomenon in design practice of Ukraine with no, if at all, special recommendations for their improvement in the national normative documents, it is necessary to consider possible functional and planning schemes for organizing the territory of childcare centers of integrated-attached type. Taking into account the fact, it is reasonable to place integrated-attached childcare centers in high-rise residential and public buildings, which are being built in different urban-planning conditions (consolidation of existing housing, historical zones of cities, peripheral districts), the playground area may differ significantly. In this sense, it is proposed to consider three main types of sites for childcare centers of integrated-attached type: *large, optimal and minimal territory* of a childcare center of integrated-attached type.

In order to calculate the optimal area of a childcare center of integrated-attached type, it is recommended to consider 30 m² per a child (place). According to the type of adjoining the territory to the building of a childcare center of integrated-attached type, three types can be distinguished: with joint, with separation and at a distance from the building (fig. 3).

A large (more than recommended calculation) territory of a childcare center of integrated-attached type, which is characteristic of new buildings in the peripheral areas of the city, allows to comfortably place the main and additional functional zones, including large areas of planting, landscape design and improvement. The optimal territory of a childcare center, which is characteristic of the residential areas with free areas for new construction, allows to place the main functional zones. Within the minimal territory of a childcare center of integrated-attached type, which is characteristic of the compacted central and historical residential areas of urban planning, it is recommended to design a universal playground area, for different age groups, without isolating the service zone.

Each of the specified types of territories of kindergartens should include the following *main components of functional areas*: play, sporting and service zone.

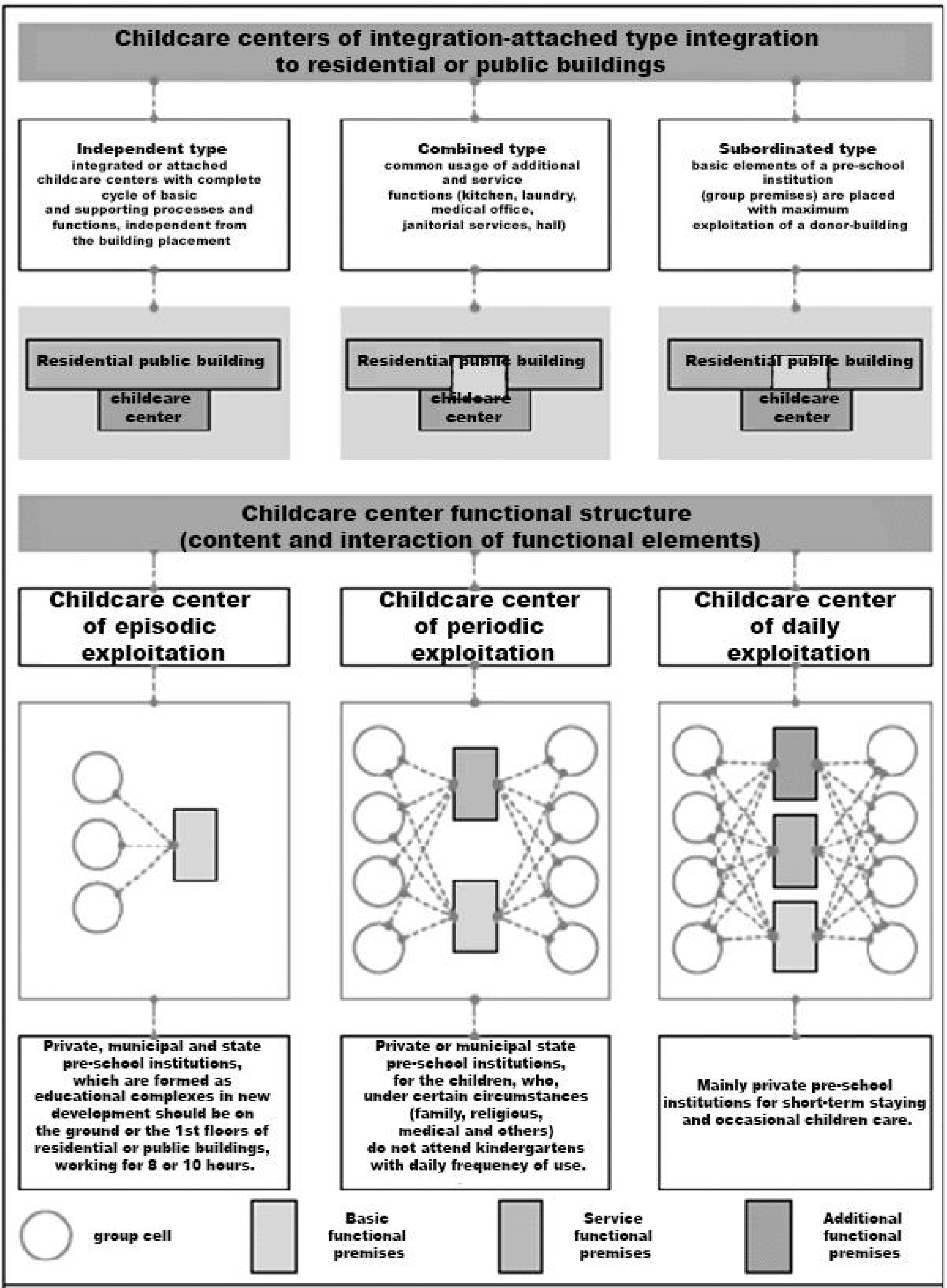

Figure 3. Integration degree and functional schemes of integrated-attached childcare centers

Besides, if possible, the territory of the pre-school institution may include *secondary functional areas*: educational area, recreation area, planting, research, artistic, thematic, plant cultivation areas, playground to study traffic rules, etc. The number of functional zones, their composition and size are determined by the design project depending on the individual features of the territory and its type.

The main components of the functional zone. The playing area includes playgrounds, individual for each group, with the optimal area being calculated as 8m² per child. Group playgrounds for preschool-aged children are proposed to be designed as specialized and thematic. Specialized areas include: playgrounds for games with sand and water; for games with building material; for socio-dramatic games; for physical games; for quiet creative games and classes; for games with large-sized mobile toys. Thematic areas may include the following: “Transport”, “Theater”, “Construction”, “Adventure”, “Zoo”, “Fairy Tale”, “House”, etc. Specialized and thematic playgrounds are reserved for the respective groups, but are used by different groups of children in turn. It diversifies the activity of children, provides additional incentives for physical and emotional development.

The PE and sports area provides general physical sport ground with an area of 150 to 250 m², as well as free seats on individual group playgrounds for sports exercises. Planning, organizing and equipping of PE playground should provide conditions for doing morning exercises with children, playing physical games with sports elements, PE classes, sports and game fests. It is recommended to have a green lawn on the common sports ground for physical games, a circular or straight running track, pits for long and high jumps, a playground for team sports games, a zone with PE equipment, gymnastic and sports equipment, and an “obstacle course”.

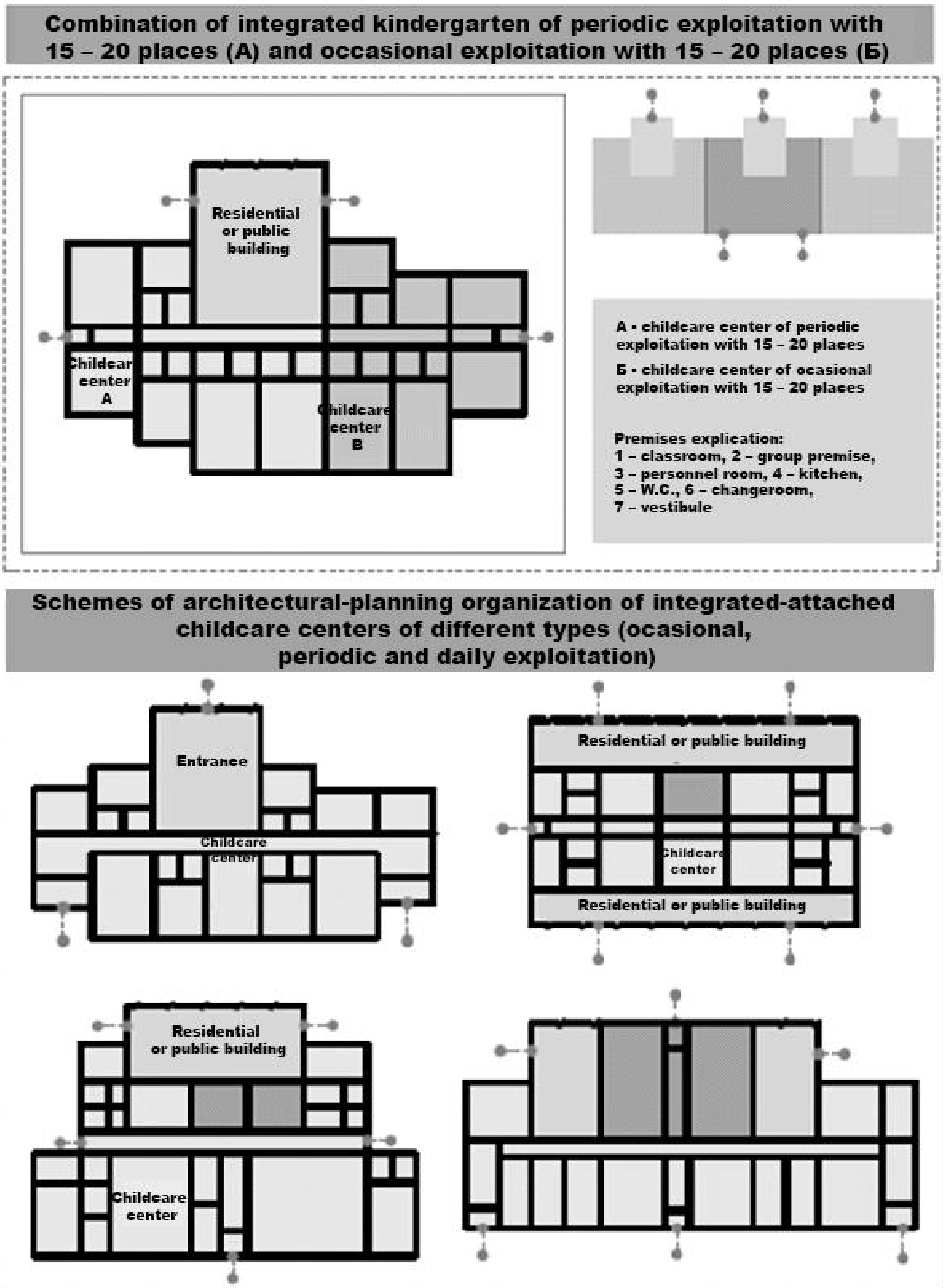

Figure 4. The scheme of architecture-planning organization of integr ated-attached childcare centers of different types (occasional, periodic and daily exploitation)

The service zone includes a public utility site with a place for unloading a garbage collector with an area of 100-50 m². The public utility site should be located at the entrance to the catering place loader. Garbage collectors can be placed on an asphalted site at the entrance to the area from the service road. At the territory of the pre-school institution, a vehicle access to the public utility site should be of minimum length and without crossing the pedestrian tracks to the group playgrounds.

The main component of a childcare center territory is the playgrounds, which serve as a kind of "attraction poles" for children of different age groups. Thus, there is a need of special care to the issue of creating an individual and contextual embodiment of the architectural and planning form of the playground, introducing a number of architectural and artistic means of improving the walking area in accordance with the age characteristics of children in pre-school institutions.

Conclusions.

1. The author has systematized the state of research of architectural and typological foundations of childcare centers development, outlined the issues that need to be studied. It is established that there are no complex investigations of childcare centers of integrated-attached type.
2. The author has substantiated the research general methodology on the basis of complex functional-structural analysis (on-site inspection, statistical generalizations, graphical-analytical systematization of the received data, complex analysis of external factors, structural functional-planning modeling, recommendations on architectural and planning solutions of childcare centers of integrated-attached type). The requirements for the childcare centers design (fire safe, sanitary-hygienic, energy-efficient, and environmental) have been systematized.

The factors influencing the childcare centers design (pedagogical, urban, environmental, socio-economic, demographic, psychophysical) have been structured. The author has classified the childcare centers according to different features: according to the type (nursery, kindergarten, day care centers, etc.); according to the function (general, specialized, sanatorium, combined ones); according to the age group (up to 3 years of age, 3 – 6 years of age, 6 years of age, combined ones); according to the type and time of exploitation (year-round and seasonal ones, short period staying ones, day, overnight and weekly ones, mixed type); according to the capacity (very small, small, medium, large capacity, complexes); according to the groups completeness; according to the degree of integration to the buildings (separate, attached, integrated ones); according to the childcare centers of integrated-attached type arrangement; according to the number of stores (1, 2, 3-storeyd buildings). The research has considered the features of space planning decisions depending on the climatic conditions (centralized, blocked, closed, semi-closed, tiered, gallery ones). The author has proposed interconnection schemes of the main premises of the childcare centers of integrated-attached type, their functional schemes (group centers, premises for musical, PE, training classes and games, medical premises, laundry and catering place).

3. The following architectural and planning principles of childcare centers of integrated-attached type and methods of their realization have been determined: accessibility principle (blocking and access methods), integration principle (contingence and contacting methods), co-operation principle (additions and interactions methods), transformation principle (versatility and flexibility methods), environmental friendliness principle (natural generation and energy efficiency methods). The childcare

center's territory should include a promenade area, pedestrian paths, sidewalks, lawns and planting zones, public utility site with a passage. The general requirements for childcare center's territory should include: safety measures, a shed protecting from precipitation and heat, landscaping, game equipment. The author has proposed the types of childcare center's sites (large, optimal and minimal territory). The architectural and planning organization of childcare centers of integrated-attached type depends on the degree of integration (independent, combined and subordinated ones) and is on the basis of the exploitation cycle (daily, periodic, occasional, and mixed types).

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CHAPTER 2.

Ievgenii Klymenko, Iryna Grynyova.

Influence of damages in structures while optimizing design decisions in civil engineering

Abstract. In modern construction to optimize the engineering solutions for the reconstruction and further normal operation of buildings and structures were analyzed residual bearing capacity of damaged structures. To optimize structural solutions during the construction and reconstruction of civil buildings, an experiment and experimental-statistical modeling of the influence of various factors on the bearing capacity was planned and carried out. In the course of experimental and statistical studies, an experiment was planned on the three most significant factors affecting the residual bearing capacity of damaged stone pillars of rectangular cross section, namely, the depth of damage, the angle of inclination of the damage front along one of the main sections and the eccentricity. The experimental statistical modeling of the eccentrically compressed rectangular cross-section damaged during the operation of stone pillars was carried out in the PC “Compex”. The results of experimental statistical modeling made it possible to determine the effect on the throughput of each of the selected factors, as well as the mutual influence of the factors. Based on the obtained values of the destructive force for 15 brands of columns, in accordance with the experimental design, a three-factor experimental-statistical model of the second order was constructed. This model is adequate for an experiment with an error of 0.45, s 7 statistically significant factors. According to estimates of the experimental statistical model and one-factor local fields, the depth of damage in the cross section of the column has the greatest influence on the bearing capacity. From the analysis presented by the diagrams of the biggest factor, you can see that the

maximum runtime of the Ru is visible in the colony at a certain day of daylight (a = 0 mm) and at the same time there is an approximate 3.

Key words: civil engineering, residential construction, software complex, experimental-statistical modeling.

Introduction. Multifunctional buildings are one of the promising types of architectural objects in modern urban development. Their construction and reconstruction are developing rapidly and dynamically, being a sought-after object of investment in Ukraine and in the world as a whole.

The even accelerating technological development and the transformation of the changes in the economic structures having taken place in the 1970's and 1980's have resulted in the close-down of factories and plants all over Europe. In our country, this process comes to the fore with the social transformation in the early years of the 1990's. After the liquidation and disintegration of the companies, several buildings are illutilised, unexploited and a significant part of them is uncared and is in bad repair. One part of such industrial buildings, however, is of historic value, i.e. they must be saved. Due to financial, rationalization and utilization reasons, the classic monument protection, scientific exploration and restoration can only be carried out for a few buildings. The reuse of the buildings is more effective method of preservation that can be extended to a wider circle of buildings.

The presentation of the re-used buildings and the scientific analysis of the examples may help us to avoid the demolition of the valuable industrial building by changing their function. Most of all, the domestic and foreign literature, mainly the papers published in architectural journals refer to the presentation of some examples of the changes taken place in the function of the buildings concerned. Beside such presentations, however, there are studies offering a more complex approach of the issue of the changes in the function of the industrial buildings. [1, 2, 3, 4]. When analyzing the re-used buildings [5], a German study uses a grouping by the following new functions: a) industry, industrial yards (Gewerbehof); b) services, commerce and gastronomy; c) flat; d) social infrastructure; e) mixed usage; f) temporary/pre-utilisation. This grouping like this may satisfy an investor's requirements, but it's ill-qualified to consider architectural and technical points. The main points to considered are not only the location, town-structural issues, and the social effects but also the economic, monument protection, structural and architectural points, which are, however, of less importance.

The original static system, the construction technology, the earlier use and the maintenance of the building influence significantly the conditions prevailing before the re-use. The structural system and the elements of the construction determine materially the architectural solutions to be applied for the re-use. The technical refurbishment and rebuilding take a significant part from the investment budget. The survey of the building and the various load carrying parts and the static examinations (checking the load capacity) are essential factors for the planning of the re-use. To see whether the building is suitable to reconstruction, a preliminary survey of the condition of the constructions and static examinations are needed.

The condition of the load carrying structures of the building determines the required and possible modifications. The required inspections are listed in Table 1.

Stone materials from ancient times, as well as the wooden materials, form the basis of construction, so the existing monuments of history and architecture, in the vast majority of them, were made of solid red brick on limestone and complex solutions.

It is known that a large part of them is located in large cities. These are historical centers of not only Ukrainian, but also European cities and separate houses and churches.

Table 1 – Grouping the examinations

Search for written or drawing sources	Search for the original designs of the building and knowing the construction history (rebuilding, refurbishment)
Survey of the building	Documentation of the present floor-plan, sections and facades of the building
Visual inspections	Condition survey of the building by e. g. room list method or building element procedure
Non-destructive testing	Checking the condition of the building structures by nondestructive testing methods
Exploring testing	Construction historic and building structure examinations by exploring the covered structures
Sampling and laboratory tests	Testing the building structures and materials in laboratory

Figure 1 – Diocletian Palace, listed on the UNESCO list, Croatia

Modern aggressive ecology, as well as other destructive factors, worsen seriously the physical and mechanical properties of brickwork of structures of historic buildings. This suggests that brick buildings and architectural heritage buildings today are in dire need of their protection and timely restoration.

Attempts to restore architectural monuments have been already known in antiquity, but until the XVIII-XIX centuries they usually were reduced to simple repair or to restore an object with actual changes in the current history of history. As an independent discipline, the restoration of monuments originates in the middle of the XIX century. in the framework of the Christian worldview, in which "time is evaluated as a directed process with beginning and end, past and future. Therefore, the possibility of irreversible loss of those values that form the fundamentals of culture, and hence the requirements for their unconditional preservation "[6, p. 32]. By this time, mostly engaged in repair, adjustment, and it was this value that was put into the very term "restoration".

The preservation of the industrial heritage in not always rational, possible and profitable. The preservation of the buildings is often made by re-using. When re-using a building, the original industrial activity will be discontinued in the building or buildings. In such case, the future of the industrial building can be demonstrated as shown in Fig. 2 [7].

The individual stations of the process are worthy of analysis, because they can be the direct or indirect precedents of a change in the function while the demolition appears as the alternative of the usage.

The purpose of the research. Nowadays for further reconstruction or re-equipment of existing facilities for the purpose of their further exploitation, in turn, requires the availability of a universal method for assessing the actual state of the structural elements of such buildings and structures.

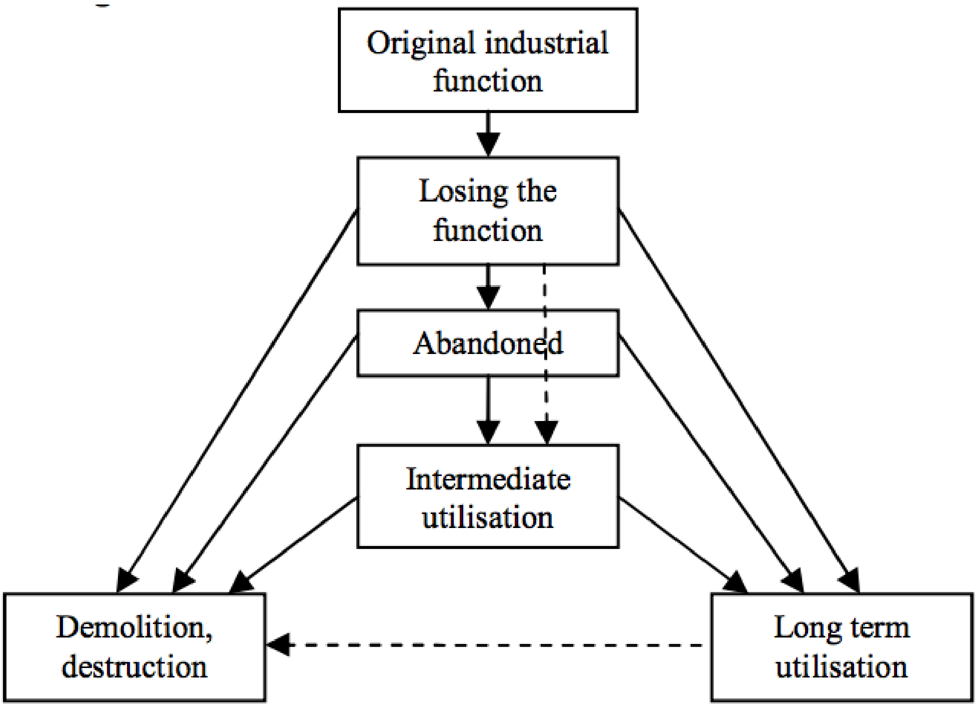


Figure 2 – Future of the industrial building after losing function

Relevance of work. To make correct design decisions, it is necessary to statistically simulate the effects of different types of damage on the bearing capacity of structures. The problem of estimating the residual bearing capacity and reliability of elements of stone structures has also recently intensively increased due to the fact that the age of a significant part of buildings and structures in the historical part of European cities and in Ukraine, which were built 50 and more years ago, are approaching normative term of service.

In order to prevent the destruction of existing buildings and structures, as well as to optimize solutions related to the reinforcement and reconstruction of damaged structures, it is necessary to have information about their level of residual bearing capacity.

Normative documents. Existing Ukrainian norms - DBN B. 2. 6 - 162 : 2010 and European standards regulates the calculation of such elements, taking into account the nonlinearity of deformation.

The science of the strength and methods of calculating stone structures is based on extensive experimental and theoretical studies, was created for the first time in the USSR in 1932-39. Its founder was L. I. Onishchik [6]. Noncentral compression in the stone structures are the most common type of stress state. All walls and pillars of buildings, bridges, constructions, etc. Are prone to off-center compression. In this regard, the study of the centrifugal compression of the masonry was given much attention in the studies [8-11]. However, the complexity of the phenomenon, which had to meet during the solution of the problem, was so great that, to date, there is no strictly developed theory of off-center compression masonry, and the practical solution to the problem was reduced to the development of empirical calculation formulas. The features of the masonry work from different types of stone and mortar, as well as factors influencing its strength, were studied.

It is established that in a stone masonry, consisting of separate layers alternating between stone and a solution, during the transfer of effort across the intersection there is a complex stressed state and separate stones (bricks) work not only on compression but also on the bend, on the stretching, cut and local compression. The reason for this is the inequality of the stone bed, the uneven thickness and density of the horizontal joints of the masonry, which depends on the thoroughness of the mixing of the solution, the degree of alignment and compression at the laying of the stone, the conditions of hardening, etc. A stone masonry, made by a qualified mason, is stronger (by 20-30%) than that performed by the worker of secondary qualification. Another reason for the complex stressed state of the masonry - various elastic-plastic properties of the solution and stone. For example, the stiffer the solution, the worse the seams come out. On the strength of masonry can provide a great influence and shape of the bricks. If the surface in them is very distorted, the thickness of the seams turns out very uneven, and from this increases the bend of the brick in the masonry. Reducing the strength of masonry for that reason can reach 25%.

Belov V. V. [13] call a spurious analysis of the causes of defects (Table 2). To prevent the destruction of structures and accidents need to have information about their level of residual bearing capacity, reliability and residual resource. Development of new methods of numerical modeling to study the residual life of the bearing capacity by comparing the data obtained both theoretical and practical studies. Establish the most effective and modern method for assessing the bearing capacity of damaged structures on the basis of analysis of their stress-strain state.

Based on the analysis of scientific and technical literature and preliminary studies [12-15], an experiment was planned on three the most significant factors influencing the residual bearing capacity of damaged stone pillars of a rectangular cross section, namely: depth of damage, angle of inclination of the front of the damage on one of the main axes of the intersections and eccentricity.

Table 2 – Quantitative assessment of the reasons for the refusal of construction sites

Causes of Avarities	Share in total
not uniform rainfall reasons	(65-75%)
overload designs	(10-15%)
temperature deformations	(10-15%)
humid deformations	(5-8%)
special load and action	(2-5%)

General part. The tasks put in practice are reduced to the construction of a mathematical model that describes the whole set of parameters chosen by us and find the numerical values of these parameters. For practical description of the properties of the mathematical model of samples, methods of experimental-statistical planning were used, which allows taking into account the stochastic nature of the processes taking place in the investigated objects.

Given that the accepted model of the experiment is manageable, it can be schematically described using a black box model, the internal device of which is unknown, and only its inputs Xi and Yi outputs are investigated and thus the external environment is stabilized (Fig. 3).

Analysis of scientific and technical literature and preliminary studies allowed to determine the input factors and the boundaries of their scope. The transition to the dimensionless normalized variables $-1 \leq x_i \leq +1$ is performed according to the following formula: : $x_i = (X_i - X_{oi}) / \Delta X_i$ (Table 3).

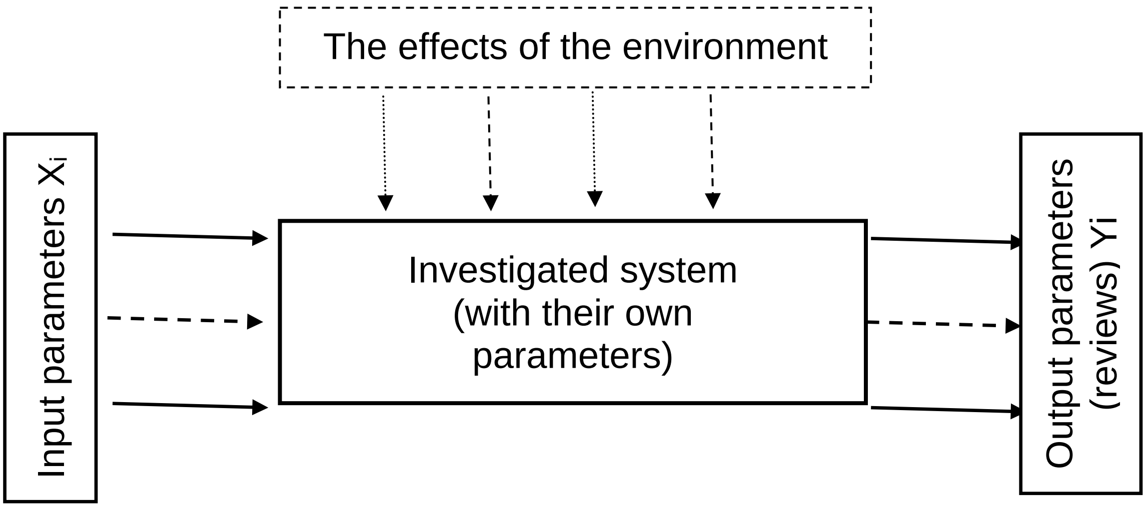


Figure 3 – Statistical model of the experiment

The obtained set of states of the investigated system allows us to analyze the dependence of the initial parameter of the bearing capacity of the samples on the determined factors x_1, x_2 i x_3. Full factorial design for three factorial experiment has 27 lines - state of the object, which is excessive for the task, therefore, for the practical optimization of the accepted experimental model, a 15-point symmetric plan was adopted. With this approach, as a result of the experiment, we will receive a statistically reliable result with a minimum number of investigated samples.

Within the planned studies were conducted test series with the pillars 15 samples of rectangular section, b × h = 510 × 640 mm, with various types of damage in the form of different depths and angles damage plane in conjunction with different eccentricity application of the external load. The variation of parameters from the experiment plan was carried out in a fairly wide (in terms of operation cases) range: the inclination angle of the damage front in one of the main axes of the cross section was θ = 0°; 22.5°; 45° damage depth a = 0 mm; 80 mm; 160 mm and relative eccentricity e_0 = 0 mm; 80 mm; 160 mm.

Table 3 – Variation of input factors

Input factors			The levels of variation			Variation interval
Code	Value	Meas. unit	«-1»	«0»	«1»	ΔX_i
x_1	The angle of inclination of damage θ	deg.	0	22,5	45	22,5
x_2	The depth of the damage a	mm	0	80	160	80
x_3	The relative eccentricitye_0/h	-	0	1/8	1/4	1/8

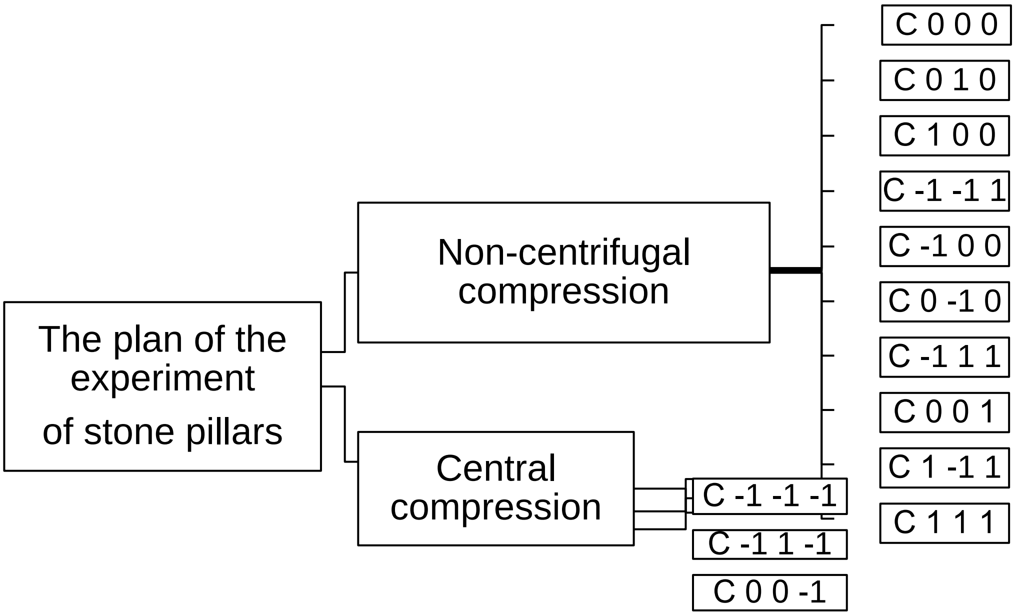


Figure 4 – Nomenclature of prototype samples

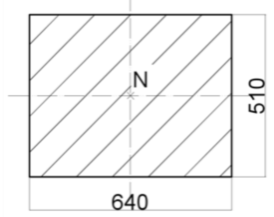
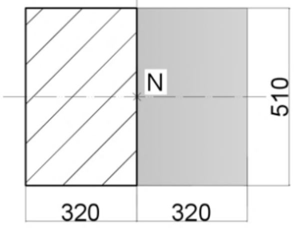
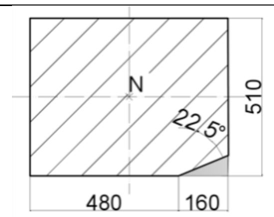
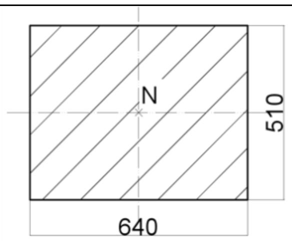
For the manufacture of samples, a ceramic ordinary full-bodied brick was used with a mark of 100 strength and cement PC II/B-S-400 of the Odessa Cement Plant and sand with a grain size module of 1.4.

The studies were conducted in the laboratory for testing building materials and products of the Odessa State Academy of Civil Engineering and Architecture.

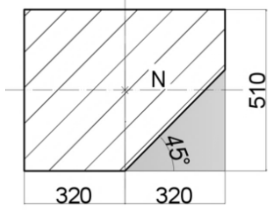
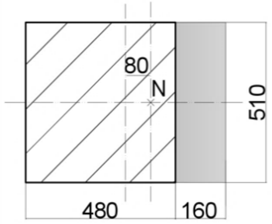
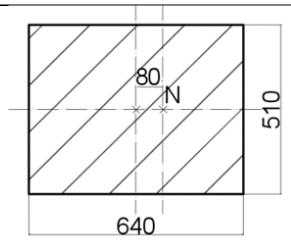
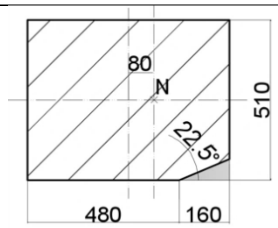
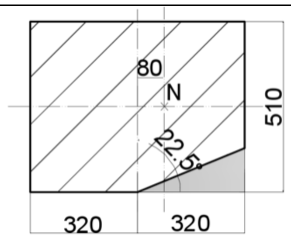
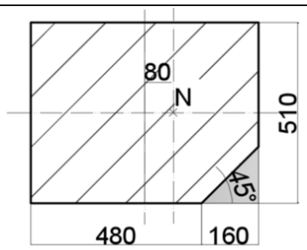
Statistical processing of the results was carried out using the PC "Compex", developed on the one Department of OSACEA. This software package allows you to evaluate the degree of influence of each factor on the samples under study. The basis of the estimation is the calculation of three factor experimental and statistical models of the studied factors of variation using the least squares method.

The formed matrix of the experiment with Physical variables of variation of the investigated parameters for a three-factor quadratic ES-model has the form (Table 4).

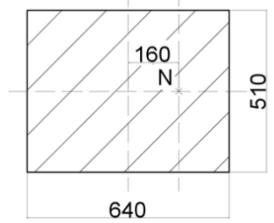
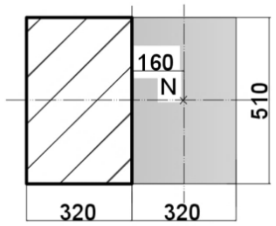
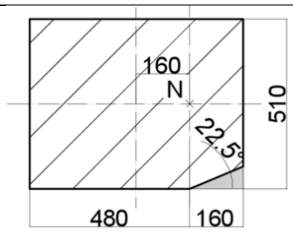
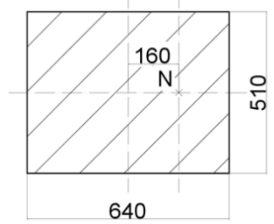
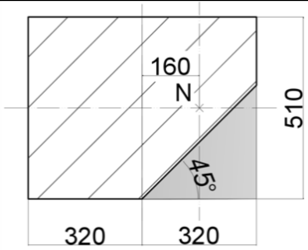
Table 4 – Physical variables of the studied parameters

Experiment No.	The coded values of factors			Actual values of variation factors			Experi-mental load bearing capacity N_{exp}, kH
	x_1	x_2	x_3	The angle of inclination of damage θ, deg.	The depth of the damage a, mm	The relative eccentric-city e_0/h	
1	2	3	4	5	6	7	8
	-1	-1	-1	0	0	0	767
	-1	1	-1	0	320	0	23
	0	0	-1	22,5	160	0	583
	1	-1	-1	45	0	0	767

Continuation of Table 4

1	2	3	4	5	6	7	8
	1	1	-1	45	320	0	453
	-1	0	0	0	160	1/8	340
	0	-1	0	22,5	0	1/8	700
	0	0	0	22,5	160	1/8	467
	0	1	0	22,5	320	1/8	447
	1	0	0	45	160	1/8	307

Continuation of Table 4

1	2	3	4	5	6	7	8
	-1	-1	1	0	0	1/4	567
	-1	1	1	0	320	1/4	10
	0	0	1	22,5	160	1/4	460
	1	-1	1	45	0	1/4	567
	1	1	1	45	320	1/4	93

Based on the received values of the destructive force ($\mathbf{R}_u$, tf) for the 15 variations of the pillars, according to the experimental plan, a 3-factor experimental-statistical model (ES-model) of the 2nd order (1) was constructed. The ES model is adequate for an experiment with the error s_e [ln{$\mathbf{R}_u$}] = 0.45, with 7 statistically significant coefficients.

$$\ln(R_u) = 4.075 + 0.497\,X_1 - 0.721\,X_1^2 + 0.634\,X_1X_2 - 1.008\,X_2 - \\ - 0.239\,X_3 - 0.374\,X_3^2 \quad (1)$$

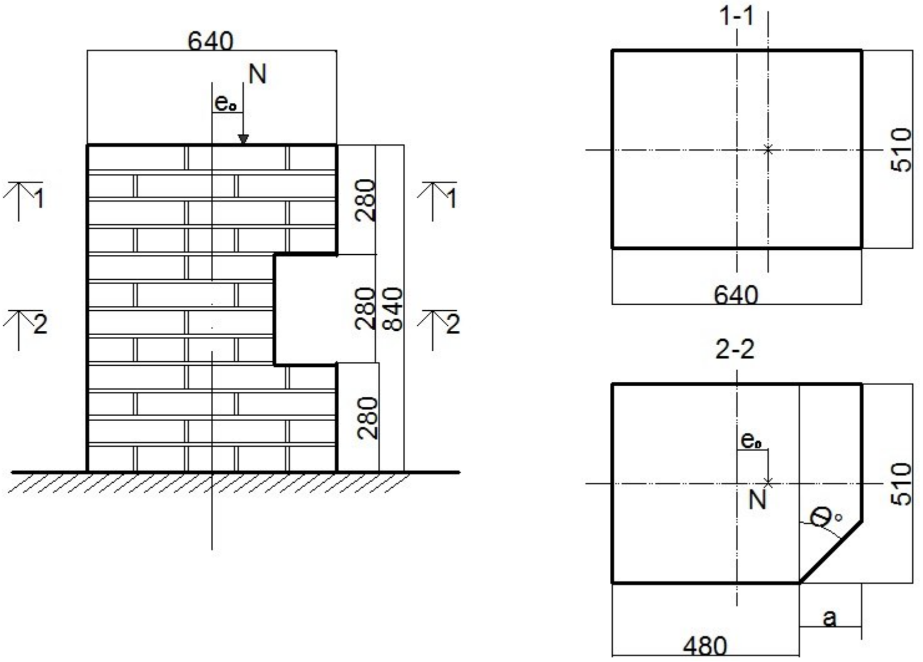


Figure 5 – Scheme for modeling of damaged sample-pillar

The main general indicators of the model in the coordinates extremes for **R*u*** include a minimum **R*u.min*** = 1,8 tf (for x_1=–1, x_2=x_3=+1) and maximum **R*u.max*** = 168,7 tf (for x_1=–0.095, x_2=–l, x_3=–0.320) levels; absolute Δ{**R*u***} = 166.9 tf and relative δ{**R*u***} = 93.7 times.

Estimates of the coefficients of the model and generalizing indicators characterize the individual and combined effects of the angle of inclination of the damage front (θ, degrees), the depth of damage (a, mm), and the relative eccentricity (e_0/h) of the cutoff on the level of destructive force. The visualization of this effect is presented on Fig. 6 and 7.

According from the estimations of the ES-model and single-factor local fields (Fig. 6), the significant influence on **R*u*** makes x_2 with the increase of the depth of damage in the section of the column significantly decreases the destructive load, so in the zone of maximum values of 8.5 times.

Due to the fact that the maximum boundary force of $\mathbf{R}_{\boldsymbol{u}.max}$ is achieved on products without depth of damage (x_2=–1), the subsequent analysis of the influence of the other two factors x_1 and x_3 is logically conducive to two factor models (2):

$$\ln(R_u) = 5.083 - 0.137\,X_1 - 0.721\,X_1^2 - \;0.239\,X_3 - 0.374\,X_3^2 \qquad (2)$$

From the analysis of the model it follows: the limiting load of sample pillars depends on the magnitude of the angle of inclination of the front of the damage x_1, and on the relative eccentricity x_3. So, with an increase in the eccentricity e_0/h (assuming x_1=–1) of the applied load, $\mathbf{R_u}$ first grows by about 18% for x_3=–0.40, and then decreases by about 47% for x_3=+1.

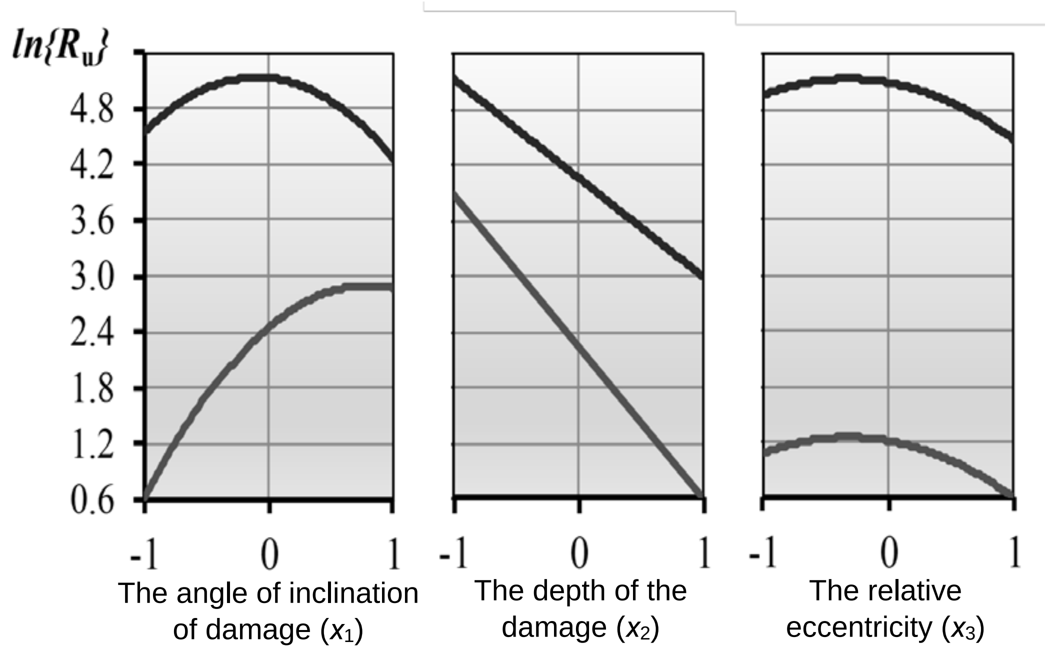


Figure 6 – Single-factor dependence of influence variation of input factors on destructive load

Influence of the angle of inclination of the front of the damage (provided x_3=–1) on the external load is slightly larger. With the change of X_1 from 0 to 22.5° $\mathbf{R_u}$ increases by 79%, and with further change of X_1 from 22.5° to 45°, the destructive load decreases more than 2 times (from 140.9 to 59.7 tf).

The analysis of the presented diagram (Fig. 7) constructed on the two-factor model (2) shows that the pillars can withstand the maximum load in $\mathbf{R_u}$=167.1 tf, but only if the angle of inclination of the front of the damage (X_1) is about 18-22.5°, and the relative eccentricity (X_3) will be about 1/8 of the applied load.

In view of the fact that the first two factors (x_1 and x_2) reflect the existing damage in the operating columns, further analysis should be carried out when the eccentricity changes (x_3). Three three-factor types (2) with different eccentricities $\boldsymbol{x}_3$ = –1, 0 and +1 have been obtained on the basis of the three-factor ES model.

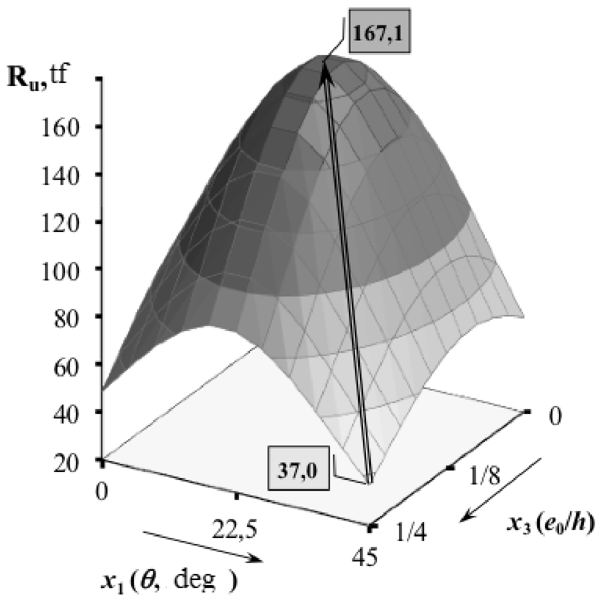
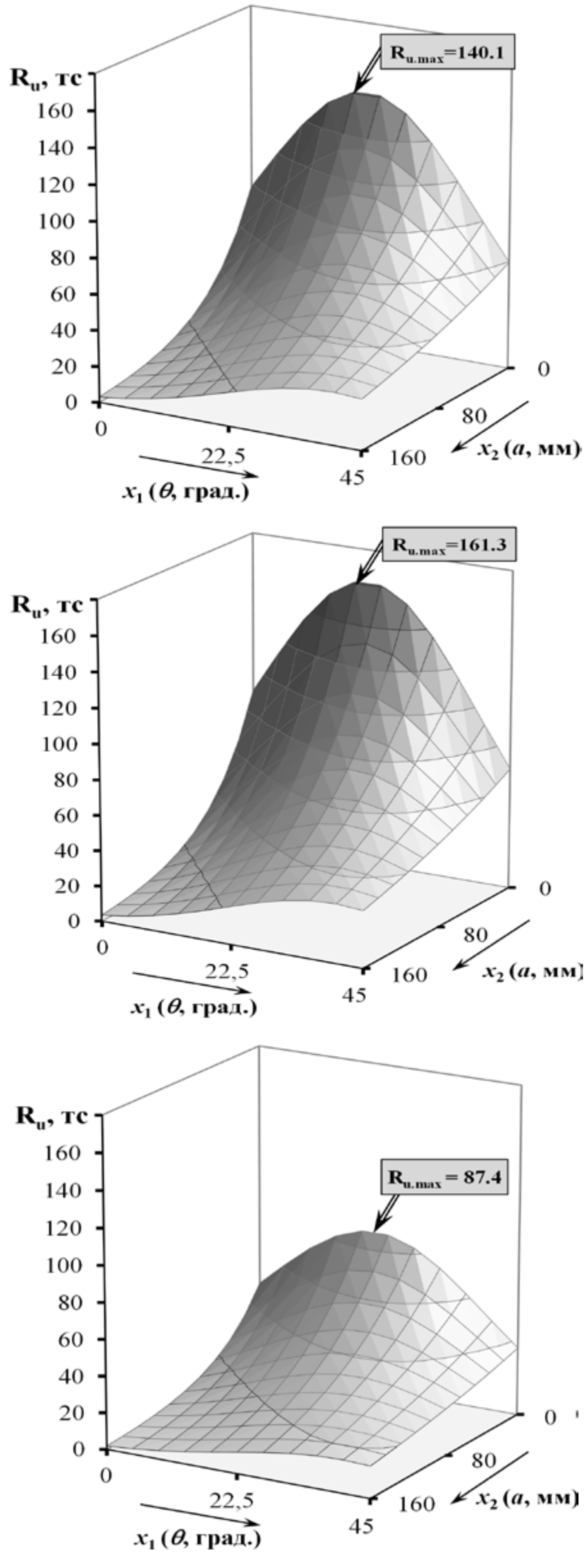


Figure 7 – Influence x_1 and x_3 on the destructive loading of the pillars in the absence of damage to the columns x_2 = –1

The fig. 8 shows diagrams constructed on the model (2), in the form of a two-factor field moving along the eccentricity scale X_3. The assessment of the degree and direction of the impact of this factor is better to use by generalizing indicators. The change in the properties of composites within a field is estimated by its absolute $\Delta\{R_u\} = R_{u.max} - R_{u.min}$ and the relative increment $\{R_u\} = R_{u.max}/R_{u.min}$.

Analysis of these diagrams allows us to conclude:

- when applying the load in the center of the pillar, the masonry can withstand Ru = 140.1 kN with an angle of inclination of the damage front of 22.5 degrees;
- when displacing the point of application of the load in the direction of the main level, the destructive force is not significantly, but increases by 21.2 tf, while the effect of the impact of various types of damage does not change. It should be noted that in the eccentricity of $X_3 = 1/8$, in the masonry, for the most part, vertical cracks appear;
- with further increase of eccentricity to the maximum level ($X_3 = 1/4$) in the laying of a stone pillar surely there are large voltages, because the boundary destructive power is rapidly decreasing. Compared to the average level of eccentricity, it is 1.84 times;



0

1/8

1/4

Figure 8 – Influence of the angle of inclination of the front (X_1) and depth (X_2) on the bearing capacity of the stone pillars (R_u, tf), depending on the relative eccentricity X_3 (e_0/h)

Conclusions and perspectives of further research.

1. A new system of conditions was elaborated in the framework of the research to be applied to the scientific analysis of accomplished re-uses and the preparation of the re-use of civil buildings. To facilitate the examinations, a new functional grouping was also introduced. By combining the system of conditions and the functional grouping, an analysis matrix can be defined.
2. The results of experimental-statistical simulation allowed to determine the effect on the bearing capacity of each of the selected factors, as well as the mutual influence of factors.
3. Based on the received values of the destructive force for the 15 variations of the pillars, in accordance with the experimental plan, a 3-factor experimental-statistical model of the 2nd order was constructed. This model of experiment is adequate with an error of 1.57 tf, with 7 statistically significant coefficients.
4. According to estimates of the experimental-statistical model and single-factor local fields, the depth of damage at the intersection of the column most strongly affects the bearing capacity.
5. From the analysis of the presented diagram of the joint effect of the variables, it is evident that the maximum destructive loading of the Ru holds the columns with no damping depth (a = 0 mm) and the angle of inclination of the front of the damage and the relative eccentricity are approximately at the main levels (X_1=X_3 0). In the further research it is necessary to develop, based on the basic preconditions of the existing norms, the method of calculating the residual strength of damaged stone pillars with various injuries.
6. The results of the research described in this section are published in the works [16-19].

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CHAPTER 3.

***Oleksiy Nikiforov, Ivan Menejljuk*.**

Optimization of civil construction under organizational and financial constrains

Abstract. The paper analyzes the numerical techniques of optimization of residential and public construction projects. The possible ways of modeling organizational and technological solutions in construction were discussed. Basing on the analysis of the most effective method of optimizing, the experimental statistical modeling was chosen in combination with modern computer programs in project management and mathematical statistics. There was developed the method of construction parameters determination of residential and public buildings using experimental statistical modeling. The results were presented of optimizing of the construction duration and the financing intensity of the shopping center construction under organizational and financial constraints. Analysis of information sources showed that civil construction conditions are extremely volatile, so it is important to investigate the effects of changing organizational decisions on key indicators, especially the duration and financing intensity of construction. There were constructed experimental statistical models of indicators changes from the varying factors: working time use intensity, number of work brigades and work processes alignment. The models, most efficient in limited conditions, were found in graphical way, according to which "the construction duration " is 244 days (60 working hours per week, 2 working brigades, 68% of processes alignment); "average monthly financing intensity" is 15.0 million UAN (80 working hours per week, 1 working brigade, 68% of processes alignment).

Key words: construction management, civil engineering, residential construction, shopping center, experimental statistical modeling.

Introduction. The volume of civil construction in Ukraine has increased by 3.4 times during the period 2010-2018 years (from 19 659,1 million UAN to 66 791,6 million UAN). At the same time, the conditions of the construction of public buildings are more complicated than other types of construction for two main reasons: engineering conditions complexity; instability of the financial situation at the macro- and microeconomic levels. The examination of the regulatory and reference literature has shown no comprehensive system recommendations for the choice of organizational and financial decisions on the topic. The implementation of investment and construction project (hereinafter – ICP) often goes with considerable difficulties, especially at the planning stage. It is necessary in many cases to consider the various organizational, technological and financial options of projects and to optimize them by the technical and economic criteria. There are needed means of graphical analysis and comparative quantitative assessment of satisfying predetermined precision, relatively simple to conduct and enabling to make decisions under existing restrictions. There are no recommendations that meet the stated requirements in the normative literature and studied information sources. Therefore, the qualitative planning of ICP requires the development of methods of modeling and subsequent optimization by the most important criteria.

Using traditional methods of modeling of ICP makes it impossible to evaluate the effectiveness of different solutions. Modeling of these options and statistical analysis of experimental models will determine the best solution for the selected performance criteria.

The **aim of the study** is to substantiate the optimization methodology and to optimize the parameters of residential and public construction (construction duration, the average monthly financing intensity) on the example of the shopping center construction under the organizational and financial constraints. The following **research tasks** were set to achieve this goal:

1. Analyze numerical methods for optimization of organizational, technological and financial solutions in construction.
2. Consider possible ways of modeling projects for the construction of residential and public buildings.
3. Analyze of Ukrainian shopping center market, especially in conditions of multifunctional civil housing.
4. Develop the method for determining the parameters of construction of residential and public buildings by means of experimental and statistical modeling.
5. Develop the specific optimization method of indicators of shopping center construction project.
6. Construct experimental statistical dependencies of construction duration and average monthly financing intensity from the working time use intensity, the number of work brigades and the work processes alignment.
7. Optimize graphically the shopping center construction parameters.

Analysis of numerical optimization methods.

The following methods of mathematical modeling and optimization of construction solutions are the most common:

- linear programming and it`s variants [1];
- optimization using graph theory [2];
- combinatorial optimization method [3];
- nonlinear programming [1];
- dynamic programming [3];
- experimental statistical modeling [4, 5, 6, 7, 8] and etc.

Advantages and disadvantages of the presented methods are shown in table 1.

Let`s consider in more detail the experimental statistical modeling. It consists of building of production processes models according to the previously approved plan, and in the subsequent finding of relationships between the optimization criteria (indicators) and the factors studied. It is done by the analysis of the built models with the help of mathematical statistics. The use of experiment planning theory helps to optimize the numerical experiment plan, which reduces the complexity of research conducting without loss of accuracy.

Application of mathematical statistics allows finding the relationship between the indicators and factors, which nature is theoretically impossible or very difficult to establish. Experimental statistical modeling has the following advantages in comparison with discussed methods:

- it allows building dependencies of optimization criteria from considered factors using a polynomial model of the first, second degree;
- it makes possible construction of empirical relationships, which allows finding dependencies, difficult to be formalized;
- it allows the analysis of the best management decisions based on several criteria at once;
- it allows ranking the factors depending on their impact on the optimization criterion;
- it provides wide range of graphical analysis application;
- it allows introducing one or more limitations both in terms of the studied factors and the value of the optimization criteria.

Table 1 – Advantages and disadvantages of numerical methods for ICP optimization

<table>
<tr><th>Method</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Optimization using graph theory</td><td>The high degree of adaptation to the ICP conditions</td><td>High complexity of created models; difficulty of optimization by several criteria at once; impossibility of using comparative graphical analysis</td></tr>
<tr><td>Combinatorial optimization method</td><td>The exact definition of the optimal solution</td><td>The extremely high complexity due to the direct search and determination of the optimum variant</td></tr>
<tr><td>Linear programming</td><td>The exact definition of the optimal solution</td><td rowspan="2">The complexity in the preparation of correct mathematical models because of the lack of quantitative selection mechanisms of optimization criteria dependences from the studied factors; use of first degree models does not always correctly display the existing dependence</td></tr>
<tr><td>Nonlinear programming</td><td>The use of high-degree polynomial model allows building highly accurate mathematical models</td></tr>
<tr><td>Dynamic programming</td><td>The possibility of adopting a chain of optimal management decisions</td><td>Narrow area of solved objectives; inability to set restrictions on the optimization criteria and the variation limits of the studied factors</td></tr>
<tr><td>Experimental statistical modeling</td><td>The relatively low complexity of creating mathematical models of a given accuracy; possibility of using comparative graphical analysis</td><td>There have not been identified for the given objectives</td></tr>
</table>

Analysis of existing project management programs was held. Most used programs are:

- *Primavera.* Software solution named “Primavera Project Management”, Oracle Corporation, has a fairly broad functionality, such as project and portfolio management, resource management, planning, project scheduling, cost management, report of time attendance and others [9].
- *Hewlett-Packard Project Portfolio Management Center.* The software allows: definition of the most important projects of the organization, use the "top-down" planning, the "bottom-up" planning on the basis of a detailed plan; monitoring the implementation of the individual project and portfolio as a whole, and others [10]. However, the high cost of the program does not allow its use in these studies.
- *Basecamp* – online tool for project management, collaboration and setting project objectives, created by «37 signals» [11]. Basecamp is compatible with many applications, widgets and other applications. Despite the widespread popularity, Basecamp is not sufficiently adapted to conduct the complex and long-term projects, as well as for large companies.
- *OpenProj* – cross-platform project management software. It is positioned as an open replacement of Microsoft Project commercial product [12]. However, OpenProj program has not yet received such widespread as its analogues.
- *Gantt Project* – program designed for project planning based on Gantt and PERT chart type. It supports import/export of Microsoft Project documents. The program is developed in Java and distributed under the General Public License [13]. This product has not yet received widespread use as its Western counterparts (Primavera and Microsoft

development environment), but is a promising program for project management.

- *Spider Project* – Integrated Project Management System. Project management technology and system Spider Project allows creation of Gantt charts, graphs and bar charts, network and organizational charts, flow diagram [14]. Along with other more well-known programs Spider Project Project Management has substantially the same characteristics, however, is less common in Ukraine.
- *Microsoft Office Project* is the most typical project management software for the Ukrainian market [15]. This fact is due to the popularity of product for project management of “Microsoft” software company – Microsoft Project. The program successfully combines project and portfolio management, in particular, enables the integration of calendar and resource planning.

Analysis of Ukrainian shopping center market.

There are now 144 shopping center in Ukraine with the corresponding lease area of 2.5 million m^2 by ICSC standards [16]. ICSC Ukraine Research Group has identified a concept of "shopping center" – an object of commercial real estate, which is planned, built and operated as a single entity, including shops and gross leasable area (GLA) of not less than 5000 m^2. According to the study, most of the retail space in the largest cities of Ukraine are presented in the format of "traditional/large" (27.9% of gross leasable area of shopping centers), "traditional/average" (23.2%), and the "traditional/small/with day to day – trade dominant" (24.7%). Another 15.8% have a format of "specialized/thematic center/entertainment without dominant" [17, 18]. Shopping centers` market development has its own logic, and from year to year it is becoming more diverse. Under these conditions, the study of organizational and financial decisions of construction of new shopping centers is relevant [19].

Development of the method for optimization of civil construction.

Let`s consider the tasks, which solution is possible by using the presented method. There are various types and kinds of solving of proposed tasks. Kind 1 is characterized by considering only the process of construction and installation works, while the kind 2 considers the process of implementation of the ICP (investment and construction project) fully from the initiation phase up to profit obtaining period. Accordingly, the type 1 is more involved in the solving of organizational and technological problems and resource conflicts, optimizing the technical solutions, while the kind of 2 – in the optimization of financing schemes and cash flow distribution. The formats of optimization solutions delivering are different too: the graph of the production work, schedules for labor resources, machines and mechanisms consumption are for type 1; the table of financial resources consumption, reflecting the selected model under the specified constraints and containing the indicators of the ICP effectiveness for each of the periods and the project as a whole, as well as the enlarged production schedules containing detailed financial information on the project.

Let`s describe the types of problems, setting of which is possible in the resented method:

- Assessment of influence and determination of the best values of the organizational and technical factors for given financial and economic conditions (comparison, selection and justification of organizational and technological solutions` strategy):
    - in conditions of predetermined funding scheme, structure and timing of funding, and the stable composition of the participants;
    - for a given level of inflation, rate of taxation, rate of depreciation;

  - for given discount rate, internal profit rate and other optimal business plan indicators [20];
  - for a given accounting method of resources consumption [21]:
    - alternative projects method;
    - opportunity cost method.
- Assessment of influence and determination of the best values of the financial factors for given organizational and technological conditions (comparison, justification and selection of financial strategy):
  - for a given method of resource/time task selection;
  - for a given schedule calculation method [22]:
    - critical path method;
    - method of continuous use of resources;
    - method of continuous work fronts development.
  - for combining processes with minimal or manageable time reserves.
- Selection of the effective strategy for the ICP implementation under the existing constraints.
- Risk assessment for the selected ICP implementation strategy (one optimal or several optional models) under predetermined conditions using a Monte Carlo method and isoparametric analysis [23, 24]. Comparative risk assessment of various strategies for the ICP implementation.
- Analysis and evaluation of the strategy for the models of the implemented ICP.

It is possible to consider an individual project, and ICP portfolio for all types and kinds. The following algorithm can be offered for variant of organizational and technological design according to the results of the conducted analysis of research materials (Figure 1):

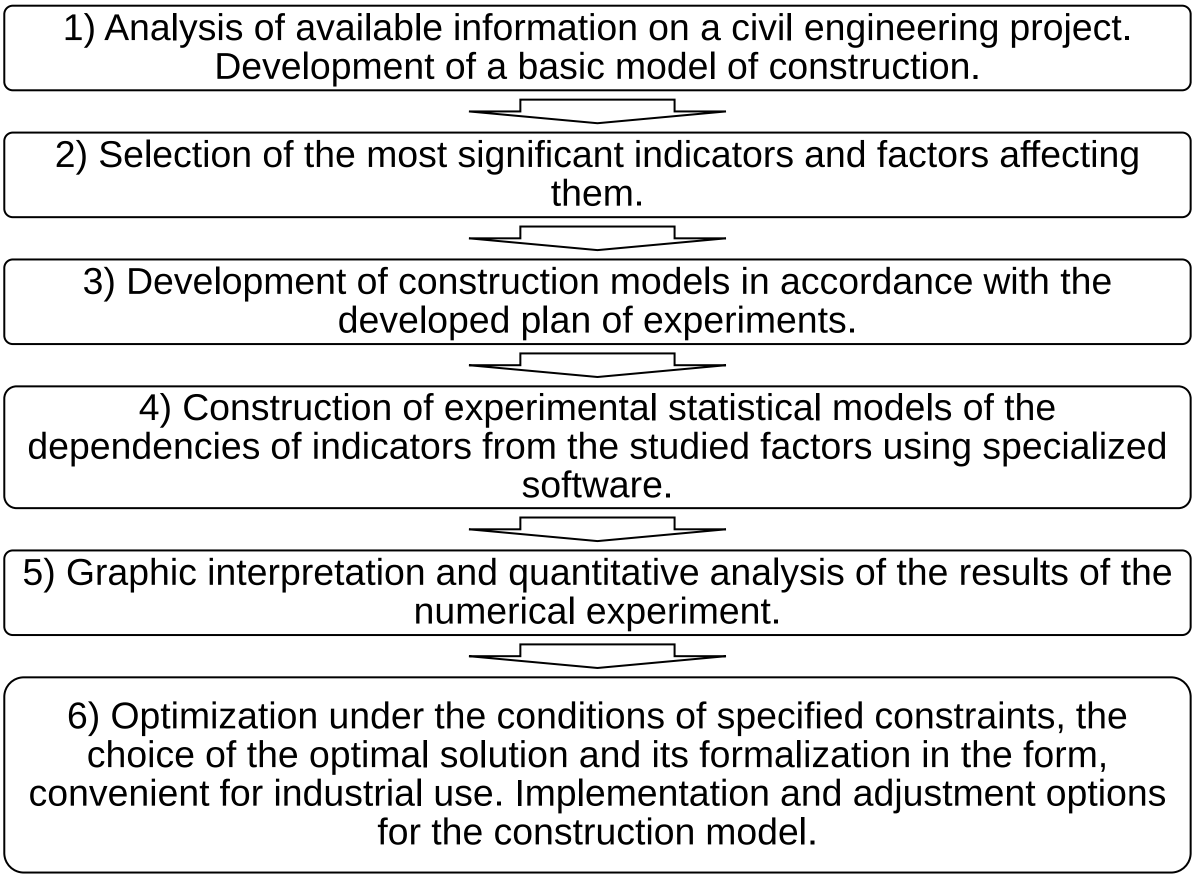

Figure 1 – Algorithm of a variant organizational and technological design of civil engineering

1. Analysis of available information on a civil engineering project. Development of a basic model of construction.
   1.1. Define and enter the work amounts and the labor costs into the project management software (e.g., Microsoft Project).
   1.2. Determine the list of necessary materials, equipment and machinery, the cost of its implementation for each process, and then enter the data into the program.
   1.3. Determine the number of workers and their wages, and then enter the data into the program.
   1.4. Calculate the required amount of working time.

   1.5. Perform mutual coordination of work in time.
   1.6. The program automatically builds a critical path and determines the time reserves in the base model.
2. Selection of the most significant indicators and factors affecting them.
   2.1. Create a list of efficiency indicators of the production processes, which have to be determined during the experimental and statistical modeling.
   2.2. Determine varying factors and changes of their levels relative to base model.
3. Development of construction models in accordance with the developed plan of experiments.
   3.1. Choose the plan of numerical experiment in accordance with the mathematical theory of planning.
   3.2. Build the necessary number of optional models in accordance with the planned schedule.
4. Construction of experimental statistical models of the dependencies of indicators from the studied factors using specialized software.
   4.1. Determine the analytical dependencies of indicators from studied varying factors using COMPEX program.
5. Graphic interpretation and quantitative analysis of the results of the numerical experiment.
   5.1. Create the graphical representations of these dependences.
   5.2. Perform analysis of the models.
6. Optimization under the conditions of specified constraints, the choice of the optimal solution and its formalization in the form, convenient for industrial use. Implementation and adjustment options for the construction model.

6.1. Choose an effective model of the project, depending on the existing limitations.
6.2. Monitor the production of works in order to meet the chosen model.
6.3. If necessary, adjust the selected model or change it in accordance with external conditions (change of construction time, funding intensity, the number of workers, machines, equipment, etc.).

Optimization method of indicators of shopping center construction project.

There was proposed to use experimental statistical modeling for effectiveness evaluation of the organizational solutions of the shopping center construction. The essence of this simulation is to monitor the system under consideration by fixing the values of the outgoing parameters when specifying input values parameters. Thus, in the present study, the system is represented as a time schedule. Experimental statistical modeling algorithm is shown on Fig. 2.

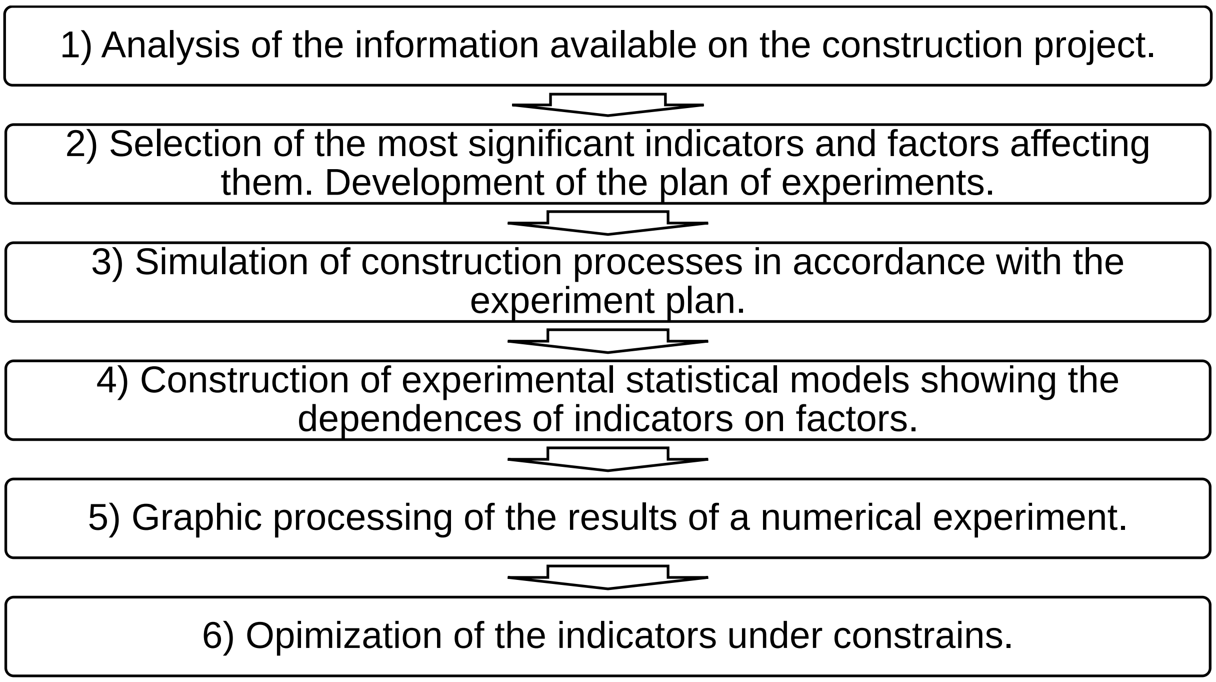

Figure 2 – Optimization algorithm

The key indicators are as follows:

- Y_1 – construction duration – the number of calendar time from the start of the first work until the end of the last work at all sections taking into account the schedule of construction works.
- Y_2 – maximum monthly financing intensity – the maximum amount of the monthly financing for the entire period of construction. It is defined as follows: construction of the schedule of works with a cash distribution equal to month period; the resulting financing schedule is analyzed and month with a maximum funding is selected.
- Y_3 – average monthly financing intensity – the funds allocated for the construction of a facility are deleted on the duration of the construction work, expressed in months.

The selected indicators are most affected by the following factors:

- X_1 – working time use intensity – there was provided the following in the development of the experimental design: 40, 60, 80 hours per week;
- X_2 – number of work brigades –there was considered embodiment of the workflow involving 1, 2 or 3 brigades simultaneously;
- X_3 – work processes alignment – the ratio of the length of the construction period T_c to the total value of the working time of all the processes on all work sections $\Sigma^N{}_1\ \Sigma^N{}_1\ t_1$ (formula 1).

The transition to the coded factor levels was performed according to the standard formula 2, where:

$$К_{allign} = \frac{T_c}{\sum_1^N \sum_1^n\ t_i} - 1 \tag{1}$$

$$x_i = \frac{X_i - \frac{X_{i\,max} + X_{i\,min}}{2}}{\frac{X_{i\,max} - X_{i\,min}}{2}} \tag{2}$$

Experimental statistical dependencies of shopping center construction. The polynomial experimental statistical model was selected to solve the problems of the present study. It`s general form is presented in formula 3. Numerical results of the experiment are shown in table 2.

Table 2 – The results of a numerical experiment

#	Working time use intensity, hours a week (X_1)	Number of work brigades, (X_2)	Work processes alignment, % (X_3)	Construction duration, days, (Y_1)	Maximum monthly financing intensity, thsd. UAH, (Y_2)	Average monthly financing intensity, thsd. UAH, (Y_3)
1	40	1	61	710	15 171, 713	7247, 944
2	40	1	76	445	20 788 647	11 487 308
3	40	3	61	278	32 012, 947	18 039 328
4	80	1	61	395	21 591 218	12 817, 417
5	40	3	76	190	43 728 903	25 907, 546
6	80	1	76	261	30 764, 955	19 025, 854
7	80	3	61	204	38 833 149	24 353, 094
8	80	3	76	141	58 253 785	30 441 367
9	80	2	68	224	44 725 436	22 139 176
10	40	2	68	335	26 268 165	15 032 774
11	60	3	68	194	50 425 694	25 367 806
12	60	1	68	409	20 667, 557	12 488, 766
13	60	2	76	190	47 045 372	25 907, 546
14	60	2	61	278	28 462 916	18 039 328
15	60	2	68	244	33 285 173	20 294 245

The results of the experimental statistical models calculation for the selected indicators are shown in formulas 4-6.

$$Y_i = b_0 + b_1X_1 + b_{11}X_1^2 + b_{12}X_1X_2 + + b_{13}X_1X_3 + b_2X_2 +$$
$$+ b_{22}X_2^2 + b_{23}X_2X_3 + + b_3X_3 + b_{33}X_3^2 \quad (3)$$
$$Y_1 = 243.64 + 73.3\,X_1 + 35.94\,X_1^2 + 47\,X_1X_2 + 19.5\,X_1X_3 +$$
$$+ 121.3\,X_2 + 57.94\,X_2^2 + 31\,X_2X_3 + 63.8\,X_3 + 9.56\,X_3^2 \quad (4)$$
$$Y_2 = 36692{,}83 + 5619{,}81\,X_1 - - 2047{,}95\,X_1^2 + 618{,}65\,X_1X_2 +$$
$$+1407{,}68\,X_1X_3 + 11427{,}04\,X_2 - - 1998{,}13\,X_2^2 + 2043{,}24\,X_2X_3 +$$
$$+ 6450{,}97\,X_3 + 209{,}38\,X_3^2 \quad (5)$$
$$Y_3 = 20377{,}52 + 3106{,}2\,X_1 - 1812{,}37\,X_1^2 - 282{,}55\,X_1X_2 +$$
$$+ 23{,}64\,X_1X_3 + 6104{,}18\,X_2 - 1470{,}06\,X_2^2 + 438{,}58\,X_2X_3 +$$
$$+ 3227{,}25\,X_3 + 1575{,}09\,X_3^2 \quad (6)$$

The isosurfaces of the indicator “Construction duration” were constructed (Fig. 3). Its values on three-factor space diagrams are displayed using isosurfaces, i.e. surfaces on which the values of the response function are equal.

The function reaches extremes at the following points on the graphical representation of the experimental statistical dependence (Figure 3):

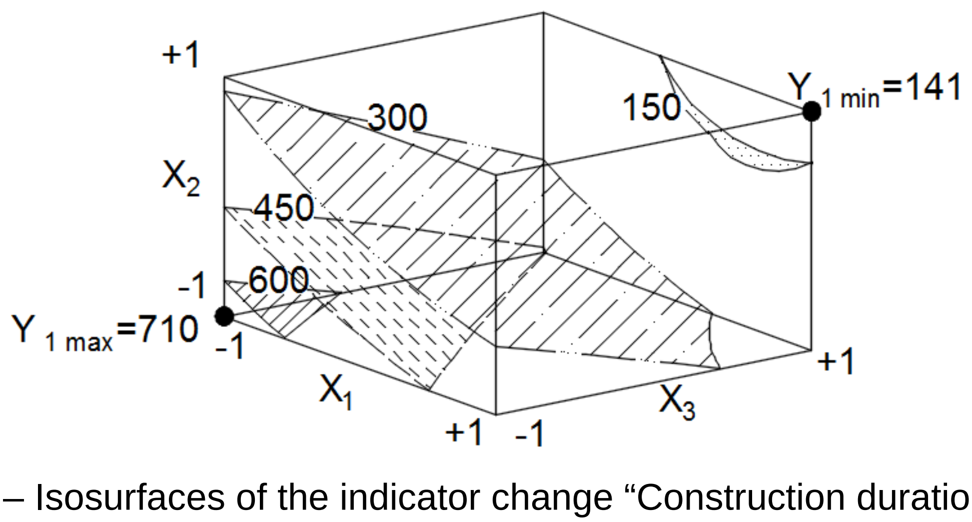

Figure 3 – Isosurfaces of the indicator change “Construction duration” (days)

- $Y_{1\ max}$ = 710 days at X_1 = 40 working hours per week, X_2 = 1 working brigades, and X_3 = 61%;
- $Y_{2\ min}$ = 141 days at X_1 = 80 working hours per week, X_2 = 3 working brigades, X_3 = 76%.

The construction duration of the Gagarinn Plaza shopping center tends to its maximum as the levels of factors X_1, X_2 and X_3 approach the minimum values (40 working hours per week, 1 working brigade and 61% process alignment). The construction duration approaches to a minimum with the striving of the same factors to the maximum values (80 working hours per week, 3 working brigades and 76% process alignment).

It is the most rational to use a graphic representation in the three-factor space (Fig. 4) to predict changes of the “Maximum monthly funding intensity” indicator while varying the number of working hours per week, the number of working brigades and process alignment. The indicator`s isosurfaces were constructed for this purpose. The values of indicator on such diagrams are displayed using isosurfaces, i.e. surfaces on which the values of the response function are equal.

On the graphical representation of the experimental statistical dependence shown in Figure 4, the function reaches extremes at the following points:

- $Y_{2\ max}$ = 60 162 thousand UAH at X_1 = 80 working hours per week, X_2 = 3 working brigades, X_3 = 76%;
- $Y_{2\ min}$ = 13 166 thousand UAH at X_1 = 40 working hours per week, X_2 = 1 working brigade, X_3 = 61%.

The maximum monthly financing intensity of construction of the Gagarinn Plaza shopping center tends to its maximum as the levels of factors X_1, X_2 and X_3 approach the maximum values (80 working hours per week, 3 work brigades and 76% process alignment).

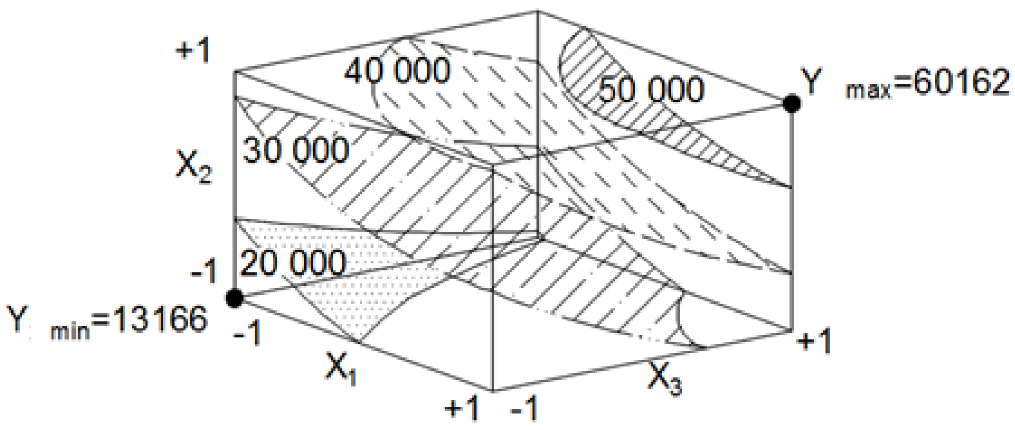

Figure 4 – Isosurfaces of the indicator change “Maximum monthly financing intensity”, (th. UAH)

The maximum monthly financing intensity of construction works is approaching a minimum when the same factors tend to the minimum values (40 working hours per week, 1 working brigade and the combined processes of 61%).

The isosurfaces of the indicator “Average monthly financing intensity” (Fig. 5) were constructed in a three-factor space.

The function reaches extremes at the following points on the graphical representation of the experimental statistical dependence shown on Figure 5:

- $Y_{3\,max}$ = 30 441 thousand UAH at X_1 = 80 working hours per week, X_2 = 3 working brigades, X_3 = 76%;
- $Y_{3\,min}$ = 7 247 thousand UAH at X_1 = 40 working hours per week, X_2 = 1 working brigade, X_3 = 61%.

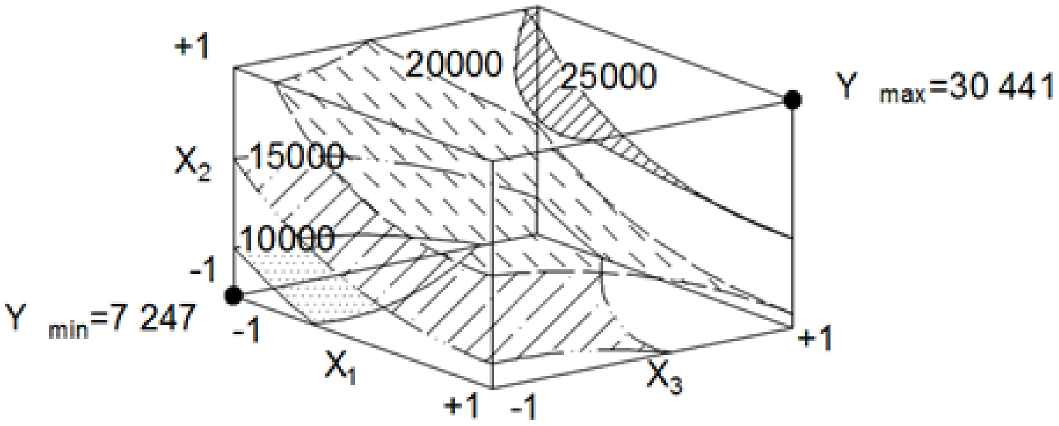

Figure 5 – Isosurfaces of the indicator change “Average monthly financing intensity”, (th. UAH)

The average monthly financing intensity during the construction of the Gagarinn Plaza shopping center tends to its maximum as the levels of factors X_1, X_2 and X_3 approach their maximum values (80 working hours per week, 3 working brigades and 76% process alignment). The average monthly financing intensity tends to minimum when the same factors tend to the minimum values (40 working hours per week, 1 working brigade and 61% process alignment).

Optimization of the shopping center construction parameters.

One of the tasks set by the customer was to determine the minimum duration of the construction work. The following restrictions were imposed:

- Work processes alignment – 68-76%;
- Maximum monthly financing intensity – 40 million UAN.

The restrictions are shown on the diagram by shading of following isosurfaces of construction duration and maximum monthly financing intensity values (Fig. 6). This allows the analysis of these restrictions.

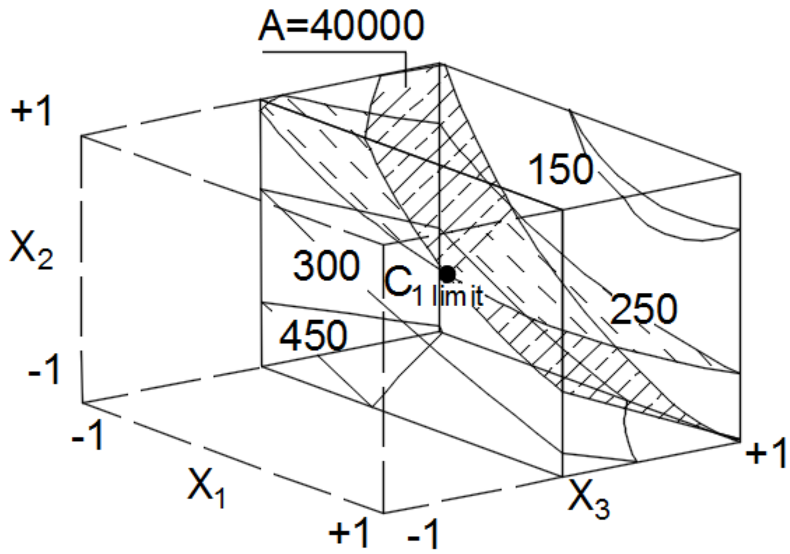

Figure 6 – Optimization of the construction duration under limitations of the work processes alignment and the maximum monthly financing intensity

The effective value of the indicator "construction duration", equal to $C_{1\ limit}$ = 244 days, was found after examining the diagram with restrictions. This model is possible at: X_1 = 60 hours per week, X_2 = 2 working brigades, X_3 = 68%. The indicator reduces by the increasing of the working time use intensity (X_1), the number of work brigades (X_2) and the work processes alignment (X_3).

Next task, set by the customer, was to determine the minimum of the average monthly financing intensity. The restrictions for this task were:

- Number of work brigades – 1-2;
- Maximum construction duration – 360 working days.

These restrictions were shown on the diagram of the average monthly financing intensity (Fig. 7).

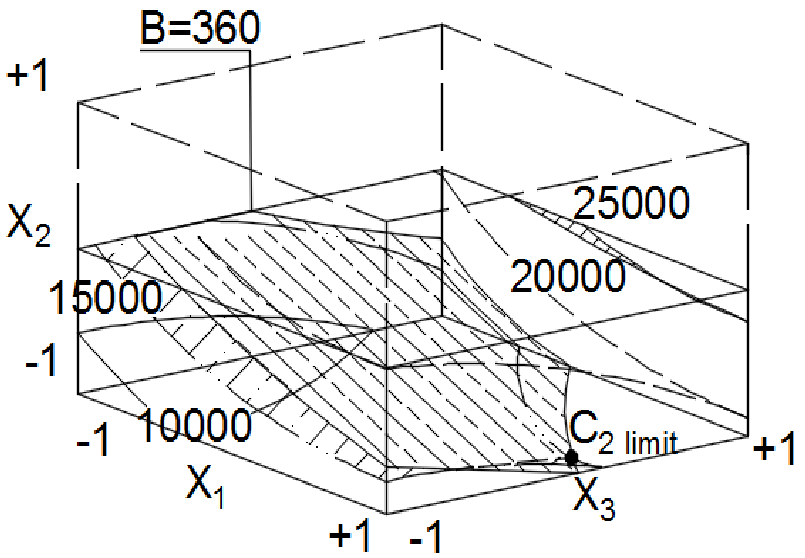

Figure 7 – Optimization of the average monthly financing intensity under limitations of the number of work brigades and the maximum construction duration

The minimal value of the indicator "average monthly financing intensity", equal to $C_{2\ limit}$ = 15,000 thsd. UAN was found after considering the limitations. This model is available when X_1 = 80 hours per week, X_2 = 1 operating brigade, X_3 = 68%. The average monthly financing intensity reduces with increasing levels of working time use intensity (X_1), the number of work brigades (X_2) and the work processes alignment (X_3).

Conclusions.

1. Analysis of numerical methods has shown that the experimental statistical modeling has several advantages that allow recommending it for solving optimization problems of the projects under consideration.
2. The most effective way of construction processes modeling is the use of project management software.

3. The analysis allowed justification of the methodology for determining the parameters of residential and public construction by the variant organizational and technological planning.
4. The efficient construction model into the investigated range of the factors has the following parameters: duration of construction – 244 days, the maximum monthly financing intensity – 40 million UAN, the average monthly financing intensity – 15 million UAN. These rates are achieved at 60 working hours a week, using two working brigades, with work processes alignment equal to 68% under constraints (work processes alignment – 68-76%; maximum monthly financing intensity – 40 million USD; number of working brigades no more than 2; construction duration – 360 working days).

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CHAPTER 4.

Oleksandr Menejljuk, Larysa Cherepashchuk.

Effective solutions of the civil engineering under the influence of organizational and technological factors

Abstract. Considering the fact that more than 70% buildings in major cities of Ukraine are high-rise, so far Ukraine demands the multipurpose civil construction. Most of the structures in this category belong to the middle class and require budgetary decisions. There have been fundamental changes over the past 12 years in the field of thermal protection of buildings – walling requirements increased. There is a necessity of finding of new effective solutions to the construction of civil buildings that meet the current requirements of energy saving and living comfort.

Keywords: construction, energy-efficient technologies, organizational factors, technological factors, modeling, building envelope.

Introduction. Civil construction is becoming increasingly popular in recent years in Ukraine. Despite the fact that over 70% of "new buildings" is high-rise (21-26 floors), opinion polls in major cities of Ukraine show that today 60% of people would prefer a single-family house apartment. Most of the people in this category belong to the middle class and require the budget homes [4]. Over the past 12 years, fundamental changes have taken place in the field of thermal buildings protection **–** the requirements for protective structures have increased. With the introduction of a regulation on building insulation [3] walling resistance has increased more than 2 times as compared to the previous version [12]. In 2008, the minimum allowable values of thermal resistance of translucent structures has changed. The map of temperature zones of Ukraine has reduced, from 4 to 2, thereby increasing the performance the minimum value of heat transfer resistance. This happened in 2013, with changes to the regulatory document №1 of thermal insulation of buildings [3]. Since 2017 works appear on updating the regulatory document of thermal insulation [4], in which, based on the European experience, it is proposed the new accounting model of the building energy. There is necessity to develop new effective organizational and technological solutions of civil construction, which lead to lower costs, but providing the regulatory requirements for thermal protection at the same time. However, there is no method of such solutions selection in modern literature. These solutions will reduce not only the cost of expenses. Such buildings implementation is largely dependent not only on the correct choice of buildings process parameters, but also on regimes of construction process. Therefore, it is necessary to examine the impact of organizational and technological factors on the construction. Experimental statistical modeling will identify patterns of indicators change of labor input, cost and construction duration under the influence of organizational and technological factors. The effective organizational and technological solutions were revealed on the basis of the constructed indicators change patterns.

Aim of the study – identification of effective walling construction solutions of civil buildings.

The essence of the main scientific objectives of the study. It is devoted to fundamental problem of choosing the most effective walling technology for the civil buildings construction solving. This objective is achieved by developing new design and technological solutions, developing patterns of construction indicators under the influence of organizational and technological factors changing, using the theory of planning of experiments, experimental statistical modeling and advanced computer programs.

Methods of study. Experimental and theoretical research method allows describing the construction processes and patterns of the indicators change on the basis of economic and graphical modeling. The theory of experimental design; method of numerical experiments, including experiments with computer simulations of civil construction processes; statistical methods in processing the experimental study results.

Analysis of the information sources. Among foreign scientists who have solved the problem in the existing constructive and technological solutions improving, as well as methods of their construction works should be noted Bartussek H., Braunisch H., Dederich L., Ehhorn H. [13], E. I. Diastry [14], Erikkson P., Fudge J., Otto F. et al. Among the research studies on various aspects of the choice of technology and organization of construction, their modeling work allocated A. I. Menejljuk [8, 9], V. G. Mlodetsky [10].

The results of research. The article presents the survey results on the basis of the numerical experiment, the theory of reduced experimental design, experimental and statistical modeling and advanced computer programs.

The study developed a new structural and technological solution walling patent UA №123124 «sandwich wall panel" [11]. The essence consists in the combined using of thin-walled components with energy efficient materials as permanent formwork and reinforced concrete (Fig.1).

Solution patent UA №123124 «sandwich wall panel" contains non-removable formwork made of extruded polystyrene 1, inner supporting layer 3 and the reinforced concrete reinforcing cage 2, anchor 5 releases from the foundation 4 to fix polystyrene. One of the objectives is to ensure the rigidity and stability of permanent formwork during installation. This is achieved by additional anchoring 4 releases from the foundation perimeter wall 5 (Fig. 1).

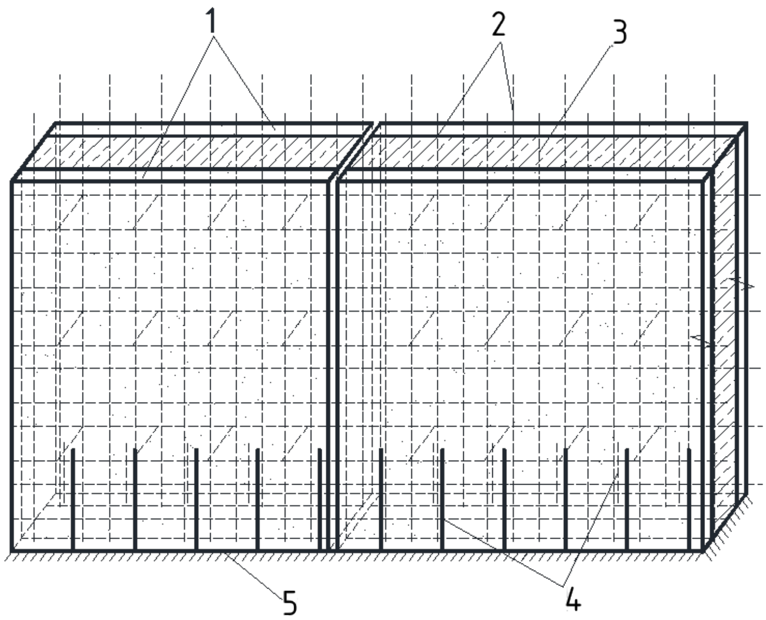

Figure 1 – General view of the multilayer wall structure:
1 – permanent formwork polystyrene foam; 2 – reinforcing cage; 3 – inner supporting concrete layer; 4 – the foundation; 5 – anchor releases from the foundation

Two parallel polystyrene foam slabs 1 are connected via rods z-shaped 6. The rods in turn are connected to the reinforcing frame 2 bearing concrete layer 3 and the reinforcing mesh 7 is installed outside polystyrene rods 1. Such a shape facilitates the connection of reinforcing mesh 7, located on the surface polystyrene plates 1 and also additional stability during assembly of permanent shuttering. Formwork liner has a shotcrete layer 8, 9 of reinforcing mesh 7. As an efficient heat insulating material used extruded polystyrene (Fig. 2).

The study begins with the planning of the numerical experiment, which includes the choice of performance of construction; organizational and technological factors that most affect the performance indicators. Then with the help of modern software solutions for pricing and scheduling information models developed construction of civil buildings. Mathematic planning theory reduced the experiment is the basis of the theory of complex experimental and statistical modeling. According to the classical theory of planning Acronym experiment, varying factors are in the range from -1 to +1. In this case the factor X_i that is the maximum value is denoted as 1, the mean value is 0 and the minimum value of the factor is -1.

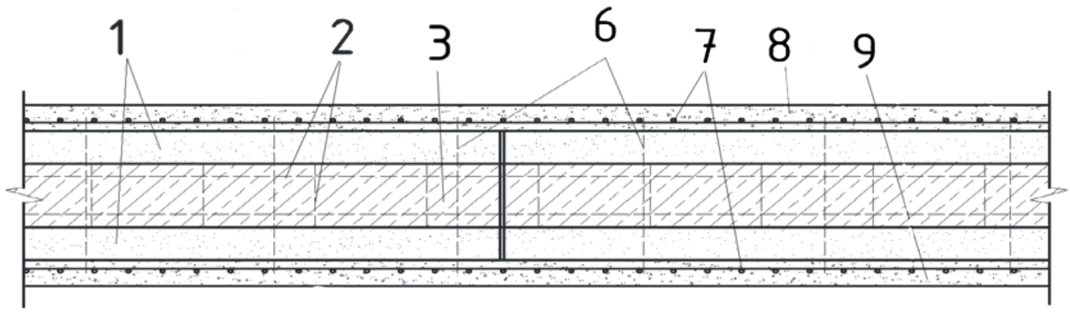

Figure 2 – Horizontal section of the wall structure
1 – non-removable formwork of foam polystyrene, 2 – reinforcing frame, 3 – internal bearing reinforced concrete layer, 6 –z-shaped rods, 7 – reinforced mesh, 8 – outer and 9 – internal layer of gun concrete

Analyzing a large number of factors, the most influential on expert performance indicator is selected. These factors are: X_1 – coefficient of working time; X_2 - the continuity of formwork; X_3 - number of process layers; X_4 - the height of the technological level.

Variation of organizational and technical factors and their numerical characteristics are presented in Table. 1.

Next, a list of works according to the process sequence and calculated the amount of work in the construction of civil buildings on the chosen technology. The models of the construction process of civil buildings construction with energy efficient protecting designs on the basis of the list and the scope of work, according to the plan developed by the experiment.

Simulation of construction processes carried out in 2 phases. On the ground - in the form of the estimates development, in the second - the implementation schedules construction on the basis of these estimates with labor using specialized software. Computer models show the calculation of future costs for the construction work and labor costs, as well as the construction period duration.

Table 1 – Factors and levels of their variation

Levels of variation	Factors			
	Organizational	Technological		
	X_1 utilization of working time	X_2 solid formwork %	X_3 number of technological levels, levels	X_4 height of the technological level, m
-1	0.24	18	1	2.5
0	0.5	50	2	3.0
+1	0.75	82	3	3.5

According to the numerical information accepted plan of civil buildings on the project "Tertia" in terms of 130 m^2, rated 25 choices of quantities. They were used for the further construction of models in the form of budget calculations and schedules of works on the construction of the chosen building with various combinations of varying levels of factors studied.

In the process of experimental research data on the cost and complexity of building processes for each experiment were obtained using a computer program AVK-5, version 3.3.1, in the form of economic model. Cost estimates include the following sections:

1. Earthworks;
2. Strip foundations monolithic;

3. The walls of the permanent formwork;
4. Precast reinforced concrete ceiling;
5. The roof and the roof;
6. Window openings;
7. Apertures;
8. Inner trim;
9. Exterior finish.

All calculations lead to the estimated calculated index 100 in terms of m^2.

The data on labor costs to the budget calculations imported into Microsoft Project program, which allowed determining the duration of the of civil buildings construction in the form of a graphical model for the implementation of production processes technology.

As a result, economic and graphic modeling options 25 budget calculations was obtained, and the same amount of performance schedules used in the experimental and statistical modeling.

Table 2 shows the results of experimental and statistical modeling of effective solutions of the civil buildings construction choice.

Calculation of experimental statistical models taken from the experimental error of 1% of the average output value. Since the estimated coefficients are statistical estimates, they require the verification of their difference from zero. Such verification was carried out at the level of risk of bilaterally in 20% ($\alpha = 0.2$), unilateral level is 10%. After settling into the program COMPEX models are tested for adequacy by the Fisher test.

After checking on the adequacy of the models on the F-Fisher test at a significance level of $\alpha = 0.05$, there were only significant coefficients in the model. If it is less critical for this risk, according to the resulting degrees of freedom, i.e. $F < F_{kr}$ (α, $f_{(to,)}$ f_e), then the model adopted for engineering decisions and analysis [1, 2, 7].

Table 2 – The plan and the results of experimental statistical modeling

№	Encoded factors				Actual factors				Indicators		
	X_1 utilization of working time	X_2 solid formwork %	X_3 the number of technological levels, levels	X_4 the height of the technological level, m	X_1 utilization of working time	X_2 solid formwork %	X_3 he number of technological levels, levels	X_4 the height of the technological level, m	The construction cost, mln UAH/ 100m^2	Labor intensity, thousands of man-hours / 100m^2	Duration, day / 100m^2
1	1	1	1	1	0,75	82	3	3,5	2975,344	3,942	67
2	1	1	1	-1	0,75	82	3	2,5	2503,483	3,551	63
3	1	1	-1	1	0,75	82	1	3,5	1640,501	2,789	44
4	1	1	-1	-1	0,75	82	1	2,5	1406,94	2,599	42
5	1	-1	1	1	0,75	18	3	3,5	1839,557	3,979	64
6	1	-1	1	-1	0,75	18	3	2,5	1592,567	3,579	61
7	1	-1	-1	1	0,75	18	1	3,5	1167,044	2,804	43
8	1	-1	-1	-1	0,75	18	1	2,5	1068,731	2,610	41
9	-1	1	1	1	0,24	82	3	3,5	2815,363	3,942	123
10	-1	1	1	-1	0,24	82	3	2,5	2359,373	3,551	115
11	-1	1	-1	1	0,24	82	1	3,5	1527,880	2,789	85
12	-1	1	-1	-1	0,24	82	1	2,5	1302,025	2,599	82
13	-1	-1	1	1	0,24	18	3	3,5	1680,366	3,979	110
14	-1	-1	1	-1	0,24	18	3	2,5	1449,062	3,579	111
15	-1	-1	-1	1	0,24	18	1	3,5	1054,756	2,804	83
16	-1	-1	-1	-1	0,24	18	1	2,5	964,057	2,610	78
17	1	0	0	0	0,75	50	2	3,0	1305,031	2,913	47
18	-1	0	0	0	0,24	50	2	3,0	1187,864	2,913	91
19	0,02	1	0	0	0,5	82	2	3,0	1775,058	2,903	66
20	0,02	-1	0	0	0,5	18	2	3,0	1180,325	2,923	64
21	0,02	0	1	0	0,5	50	3	3,0	1797,875	3,774	87
22	0,02	0	0	1	0,5	50	2	3,5	1334,891	3,031	67
23	0,02	0	-1	0	0,5	50	1	3,0	1123,025	2,700	58
24	0,02	0	0	-1	0,5	50	2	2,5	1199,737	2,817	63
25	0,02	0	0	0	0,5	50	2	3,0	1255,355	2,913	65

The results enable us to determine the construction cost at different values of the organizational modes construction and technological parameters of the building. Effect of working time utilization, the continuity of the formwork, the number and height of the technological level at the construction cost is represented as a mathematical model (1):

$$S = 1{,}252 + 0{,}064X_1 + 0{,}351X_2 + 0{,}236X_2^2 + 0{,}154X_2X_3 + 0{,}045X_2X_4 + \\ +0{,}431X_3 + 0{,}219X_3^2 + 0{,}047X_3X_4 + 0{,}122X_4 \quad (1)$$

This mathematical model shows that the value of all the coefficients of the factors X_1, X_2, X_3, X_4 less than one and have a positive sign. A positive sign indicates that the change in proportion to the value of these factors change, that is, with increasing X_1 (utilization of working time), X_2 (solid formwork), X_3 (the number of technological levels), X_4 (the height of the technological level) within their varying levels of increased cost. The greatest influence on the analyzed component has X_3 factor (the number of technological levels) with a coefficient of 0.431 at its normal impact. A further factor in the degree of influence on the active component is X_2 (solid formwork) with a coefficient of 0.351 at normal form. The least effect on the cost factor is a factor X_1 (utilization of working time), since it is an organizational. In this case, the coefficient is only presented in normal form and effect equal to 0.064.

The impact of each factor on the construction cost in the area of their extreme values shown in Fig.3.

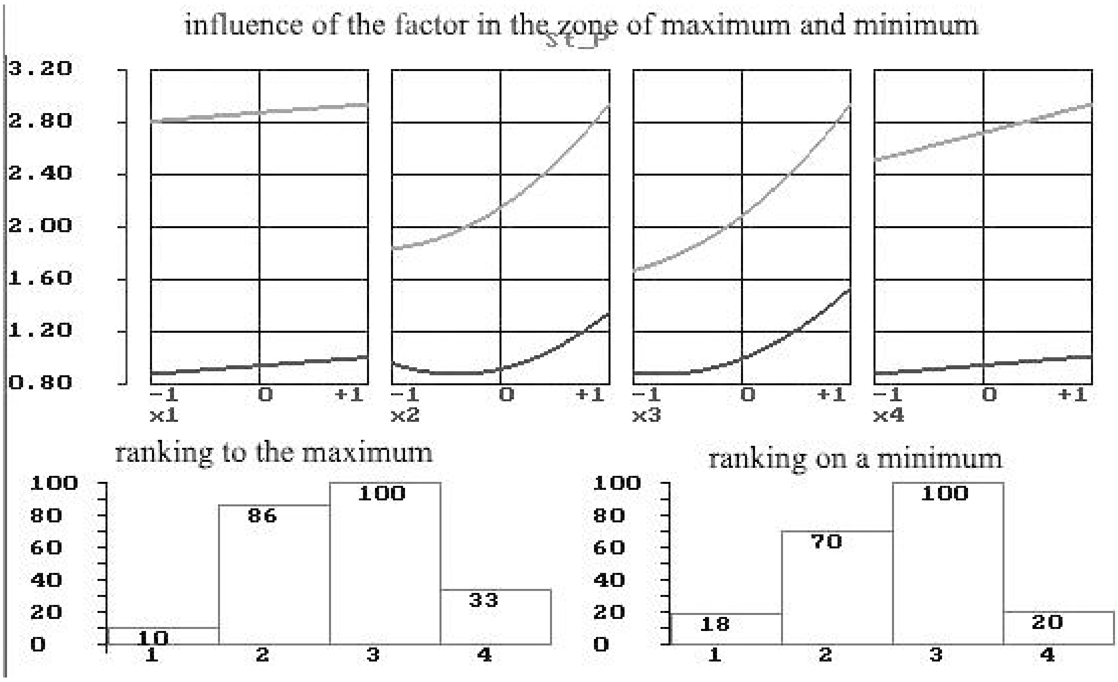

Figure 3 – Single-factor diagram in the areas of minimum and maximum for the construction cost

In this study, the highest cost depends essentially on the number of technological levels (X_3) - the rank of this factor influence in the maximum and minimum of the largest area and is equal to 100%. The more so that the maximum values of the area cost increases with greater intensity and is parabolic. Thus, when changing from -1 X_3 (1 level) and 0 (level 2) the value of the cost index is increased by 24%, i.e. from 1.7 mln. UAH. to 2.1, and when changing from 0 (level 2) to +1 (level 3) 38% - from 2.1 to 2.9 mln. UAH. The minimum values of area of 11% - is from 0.9 to 1 mln. UAH. and 50% - from 1 to 1.5 mln. UAH respectively. A little less than a significant effect continuity formwork (X_2). Steppe effect of this factor in 86% of the maximum area and 70% in the minimum area. The diagram shows that the nature of the influence factor as well as X_3 is parabolic. In the zone of minimum at values factor -1 (18%) and 0 (50%) the cost is almost the same at 0.95 mln. UAH. cost index increases when the percentage of glazing is approaching the maximum, as the cost of labor and of the panoramic glazing for 1 m^2 larger than necessary materials and wages per 1 m^2 of the wall. The utilization of working time (X_1) has the lowest influence degree, compared with the number of technological levels (X_3), - 10% and 18% at the maximum and minimum zone is rectilinear and dependence. Working time coefficient relates to the organizational factor therefore more influence on the construction duration. In this case, it appears on the construction cost via the workers' wages. Since the duration of working time changes, i.e. increasing the average working hours per month, respectively, and the average monthly salary as well.

To visualize the study results, containing 4 interdependent factors used chart type "square on the square", which reflects the impact of the four factors on the construction cost (Fig.4).

For this it is necessary to build 9 diagrams the combination of two factors and arrange them on the basic square, which allows for a combination of the other two factors. Figure 3 shows a diagram of "square in square", which reflects the influence of X_1 (utilization of working time), X_2 (solid formwork), X_3 (the number of technological levels), X_4 (the height of the technological level) to construction costs (Fig.4).

Efficiency index of construction cost is assumed at 1.8 million UAH per 100 m^2 of the building in plan. This value is based on the information of the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine. In a letter №7 / 15-945 from 26.01.2018, "On the change in the index value as at January 1, 2018" in the table №5 shows the average construction cost in Ukraine, in particular, "farmsteads with outbuildings" on at 18 146 UAH per 1m^2 with VAT. Therefore, the area in which the value is above 1.8 million UAH, are not effective, and further study excluded. Figure 2 shows the area shown by hatching (Fig.4).

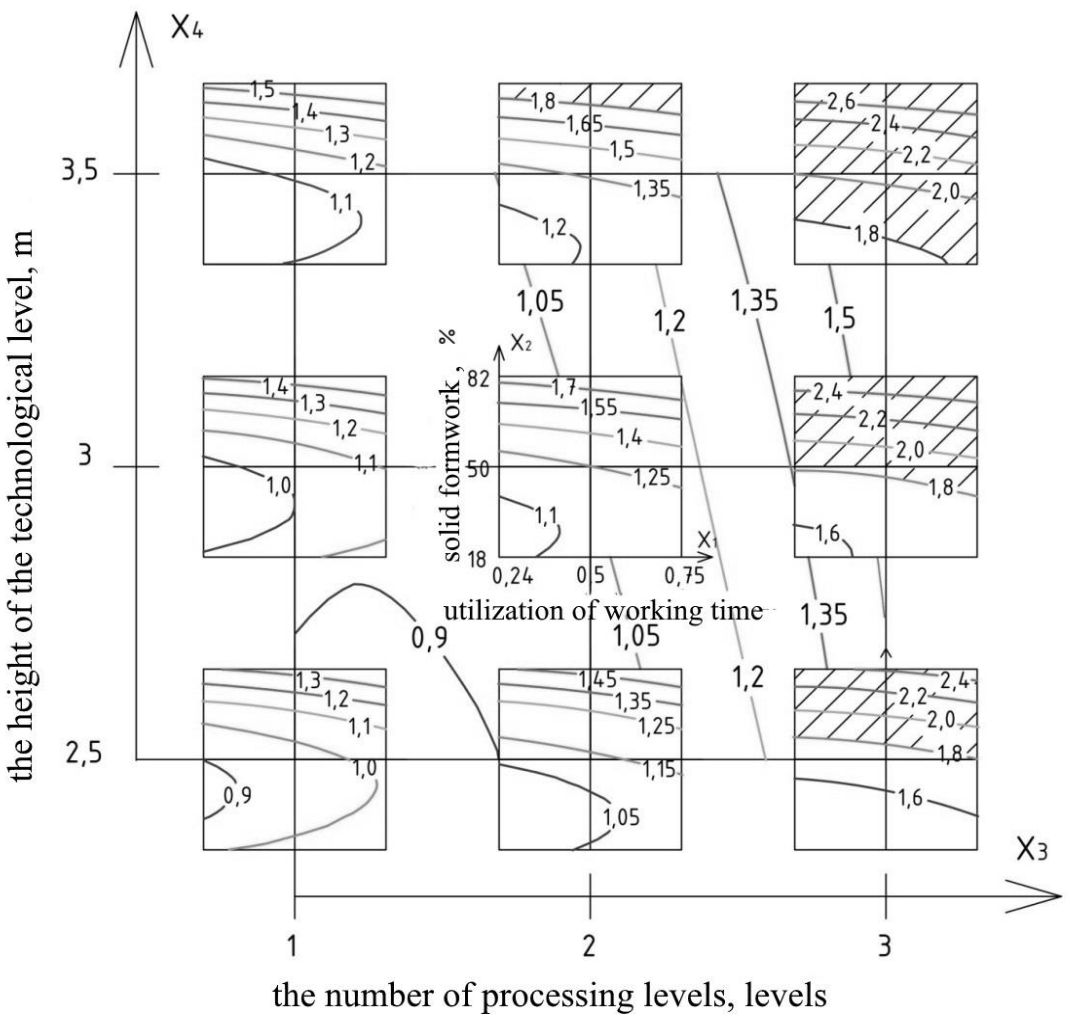

Figure 4 – "Square on the square" diagram of the influence of 4 factors on the construction cost.

As can be seen from the chart, show the value of building technology is quite effective as it allows building one, two, and even three-level home in the range of 1, 8 million. UAH. Display achieves its construction value extrema in the following points: the maximum values utilization of working time rate X_1 = 0.75 and solid formwork X_2 = 82%, the number of technological levels X_3 = 3 and the height of the technological level X_4 = 3.5, and m is equal to S = 2,921 mln. UAH. Accordingly, the most effective solution is the following factors levels: X_1 = 0.24; X_2 = 40%, X_3 = 1 level, X_4 = 2.5 m, wherein S =

0,877 mln. UAH. The effectiveness of organizational and technological solutions increases with a decrease in their values, which in turn affect the decrease in construction costs. Boundaries efficiency may reach under very different combination of organizational and technical factors. For example, with a coefficient utilization of working time X_1 from 0.24 to 0.5, X_2 formwork integrity of 18% to 34%, X_3 = 3 technological level, and the process heights tier X_4 = 3.5 m can be obtained the minimum value of the indicator that do not exceed the zone effectiveness. Therefore, such solutions allow the technology to build a 3-level house of 100 m^2 in terms of less than 1.8 mln. UAH. The most economical are the home-level 1, the maximum value does not exceed 1.6 mln, UAH. is given the highest integrity formwork 82%, the height of technology tier is 3.5 m and with the organization of work in 2 shifts at 9 hours 7 days in Week.

Also it should be noted that when X_3 = 1 (the number of technological levels), X_4 = 2.5 m (the height of the technological level), X_1 = 0.5 (utilization of working time), X_2 = 25% (solid formwork) value can be obtained 1.0 mln. UAH such as the building cost values can be achieved by increasing the factor of X_2 to 60%. Such conditions are met at various combinations of organizational and technological factors.

The results enable us to determine the construction complexity at different values of the organizational modes of construction and technological parameters of the building. Effect of utilization of working time, the continuity of the formwork, the number and height of technological complexity levels on the construction presented as a mathematical model (2):

$$T = 2{,}916 - 0{,}011X_2 - 0{,}005X_2X_3 - 0{,}532X_3 + 0{,}316X_3^2 + 0{,}051X_3X_4 - - 0{,}142X_4 \quad (2)$$

From this mathematical model shows that the factor X_1 (utilization of working time), has no influence on the complexity index. This is due to the fact that it relates to organizational factors and the complexity depends on the influence of technological factors. The greatest impact on labor intensity indicator provides X_3 factor (the number of technological levels) with a coefficient of 0.532 at its normal impact. That is, there is a linear ratio - with an increase in the technological level, the complexity increases. Factor X_2 (solid formwork) has the least impact, its coefficient is 0.011 at normal form. Considering first marks at variable degree X_2 factor (solid formwork), which is negative.

The influence of each factor on the construction duration in the area of their extremes values shown in Fig.5.

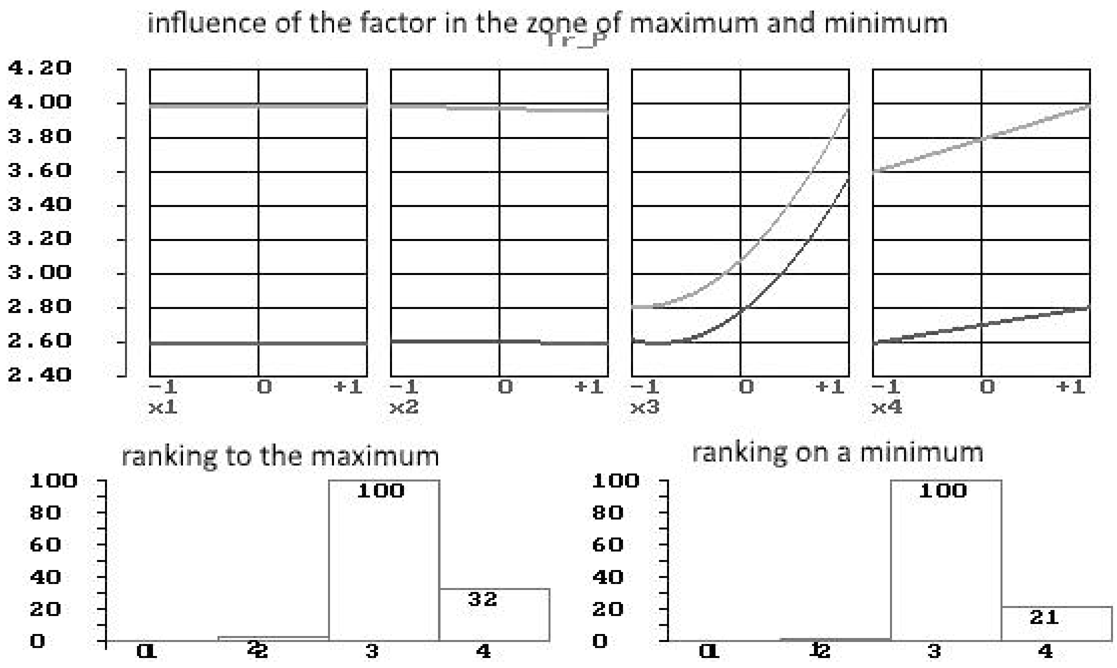

Figure 5 – Single-factor diagram in the areas of minimum and maximum for construction labor input

The comparative degree of factors influence on the performance indicator is different. In particular, the greatest degree of influence (100%) on the complexity renders X_3 factor (the number of technological levels) in the zones of maximum and minimum, which is directly proportional to the parabolic shape. When changing from -1 X_3 (1 level) and 0 (2 levels) increases the complexity value from 2.8 to 3.1 thousands of man-hours or 11%, and 0 (level 2) to +1 (level 3) from 3.1 to 4 thousands of man-hours or 29% of the maximum area. Factors X_1, X_2, X_4 have a linear ratio. Effect X_4 factor (height of process tier) is expressed not as clearly and is 32% and 20% in the zones of maximum and minimum, respectively, over the X_3 factor (the number of technological levels). It should be noted that when the X_4 factor -1 (2.5 m) to 0 (3 m) and 0 (3 m) to 1 (3.5 m) complexity is increased by 5% and is from 3.6 to thousands of man-hours 3.8-h and 3.8 to 4 hours in thousands of man-hours-peak area, and a minimum area with a lower intensity and equal to 4% - of 2.6 to 2.7 thousand, 2.7 to 2.8 thousands of man-hours. Further, it is seen that X_1 factor (utilization of working time) and X_2 (solid formwork) have no influence on the complexity index in all zones. Although by increasing the factor X_2 (solid formwork) complexity is reduced about 1%, this is due to the changing nature of the production process, i.e. increasing the glazing percentage means percentage decreases walls device, which is more labor intensive on labor costs. We can say that the factor is inversely proportional to the character. With increasing factor X_2 (solid formwork) complexity is reduced about 1%, this is due to the changing nature of the production process, i.e. increasing the glazing percentage means percentage decreases walls device which is more labor intensive on labor costs. We can say that the factor is inversely proportional to the character. With increasing factor X_2 (solid formwork) complexity is reduced about 1%, this is due to the changing nature of the production process, i.e. increasing the glazing percentage means percentage decreases walls device which is more labor intensive on labor costs. We can say that the factor is inversely proportional to the character.

In this study, the building construction work content parameter and the individual manufacturing processes are determined based on the estimated calculation program complex AVK-5. The values obtained are estimate and regulatory complexity and change depending on the work scope, project solutions, that is, the number of floors, the height of the premises, the type of basic structural elements, etc. Therefore, the efficiency is the boundary between the average values of those obtained on the basis of economic models in the form of estimates at different levels of variable factors. Thus, this value is 3000 thousands of man-hours watch. Areas in which the value is less than 3000 thousands of man-hours. They are technologically effective, and those in which more – inefficient and marked by shading. It should be noted (Fig.6).

He noted that the effect of factors on the complexity index is linear, i.e. by increasing one of the factors that increases the complexity and, in addition, as stated above, utilization of working time. The diagram shows that there are three zones ineffective. First, when X_3 = 2 the number of technological levels, X_4 = 3.5 m height technological tier at second X_3 = 3, X_4 = 3.5 m and 3 m and at all levels varying X_1 factor (utilization of working time) of 0 24 to 0.75, factor X_2 (solid formwork) from 18% to 82%. Maximum complexity to 3,973 thousands of man-hours achieved when: confluency formwork X_2 = 82%, the number of technological levels X_3 = 3 and tier adjustment process X_4 = 3.5 m. The remaining dependencies complexity changes in the diagrams presented under the influence of varying levels X_1 factors from 0.24 to 0.75 and X_2 from 18% to 82% at 6 embodiments, the number of technological levels (X_3) and the height of the technological level (X_4) are effective.

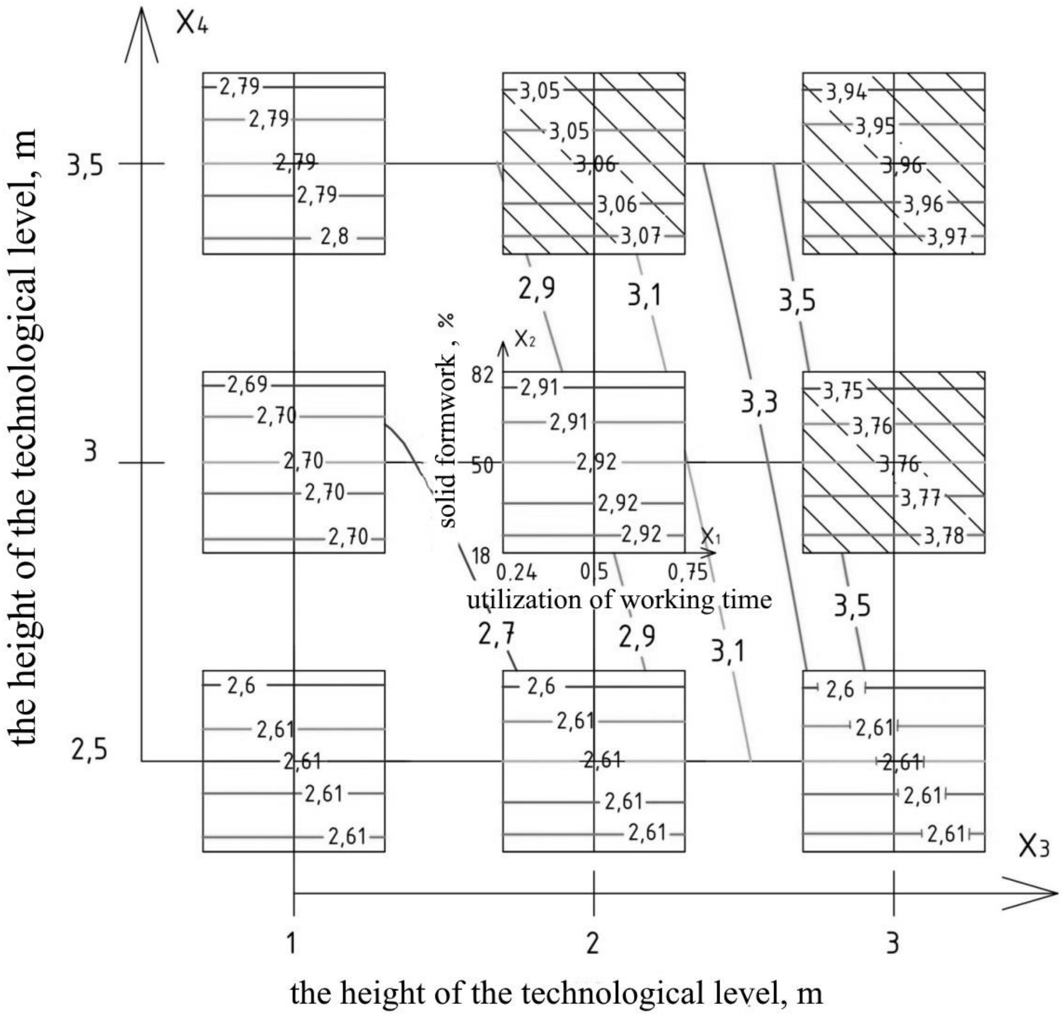

Figure 10 – "Square on the square" diagram of the influence of 4 factors on the construction labor input

The lowest complexity varies from 2,610 thousands of man-hours to 2,920 which is about 12% larger.

It should be noted that the graphs of the technological complexity of the height of the technological level (X_4) of 2.5 m and the number of technological levels (X_3) from 1 to 3 unchanged. The complexity is thousands of man-hours 2,610 is effective. This is because the complexity of manufacturing processes walling depends on the volume of work within height variation factor X_4 process level from 2.5 m to 3.5 m is not significant relative to the entire volume of the building. Especially because the complexity of construction of 1m^2 multilayer walls with permanent shuttering of polystyrene foam is 1.36 thousands of man-hours.

The introduction of new, advanced technology of buildings construction and the materials used, in particular polystyrene, characterized by the ease and installation simplicity.

The results enable us to determine the construction duration at different values of the organizational modes of construction and technological building parameters. Effect of utilization of working time, the continuity of the formwork, the number and height of the technological levels for the construction duration is presented in the form of a mathematical model (3):

$$P = 65{,}119 - 22{,}556X_1 + 3{,}584X_1^2 - 1X_1X_2 - 2{,}875X_1X_3 + 1{,}778X_2 + \\ +0{,}875X_2X_3 + 0{,}5X_2X_4 + 13{,}611X_3 + 7{,}084X_3^2 + 1{,}667X_4 + X_4^2 \quad (3)$$

Analyzing the obtained analytic dependency it may be noted that the greatest impact on expectancy has organizational factor X_1 (utilization of working time) by a factor of 22.556 at normal meaning 3,584 with a quadratic, in combination with Factor X_2 (solid formwork) ratio is equal to 1 and 2.875 at combined with X_3 (the number of technological levels), and in combination with a factor of X_4 (the height of the technological level) has no effect due to slight changes in the volume of work and labor costs in variation this factor. It should be noted sign of the coefficient. Minus sign indicates that the variation of this factor is inversely proportional to the change in the length indicator. That is, the larger the factor X_1 (utilization of working time) within the range of variable values, the lower the construction duration. Other factors have a positive sign of the coefficients and show that a change in a big way and a corresponding increase in duration. Another factor that substantially affects the indicator is X_3 (the number of technological levels) by a factor of 13.611 at normal impact and the quadratic 7.084 in combination with factor X_4 (the height of the technological level) has no influence. X_2 Odds factors (solid formwork) and X_4 (the height of the technological level) at normal exposure have substantially identical values, 1.778 and 1.667 respectively. However, it should be noted that the factor X_2 (solid formwork) affects to a greater extent, as there are factors in combination with the factor X_3 (the number of technological levels) and 0.875.

The impact of each factor on the construction duration in the area of their extreme values shown in Fig.7.

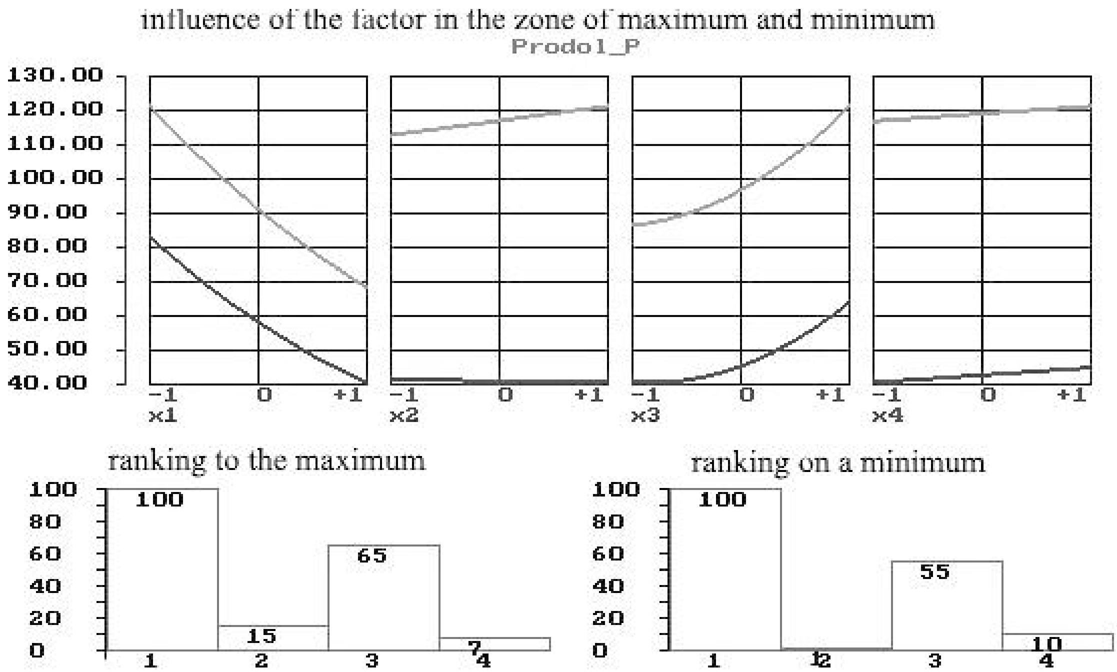

Figure 7 – Single-factor diagram in the areas of minimum and maximum for the construction duration

In this study, the construction duration depends most significantly on the operating time utilization (X_1) a maximum zone and a minimum – the rank of this factor and the maximum is 100%. Effect of Factor X_1 is parabolic.

Working time coefficient relates to the organizational factors, so in the area of maximum and minimum values construction time is reduced with the same intensity. The maximum area when changing from X_1 factor 1 (utilization of working time) shift 8 hours and 5 days per week) to 0 (working time per shift 12 hours and 7 days a week) construction duration is reduced from 122 days to 90 that is 35% to 43% and from 83 to 53 days in a minimum area. And when changing from 0 (working time per shift 12 hours. Figure 6 shows a diagram of "square in square" which reflects the influence of X_1 (utilization of working time), X_2 (solid formwork), X_3 (the number of technological levels), X_4 (the height of the technological level) for the construction duration.

To begin, define the boundary of the effective index of the construction duration (Fig. 8).

Construction time for this study was determined by using Microsoft Project software. DSTU B A.3.1-22:2013 "Determination of the construction duration projects" Annex A defines "average expectancy of construction of certain types of non-production objects and linear objects of engineering and transport infrastructure." Since organizational terms and technological characteristics of the construction are changed (X_1 – utilization of working time varies from 0.24 to 0.75; X_3 - the number of technological levels from 1 to 3), respectively, and also the length, accept the boundary level performance average value 75 days. The diagram shows that the organizational and technological solutions are quite feasible because each zone has an area efficiency.

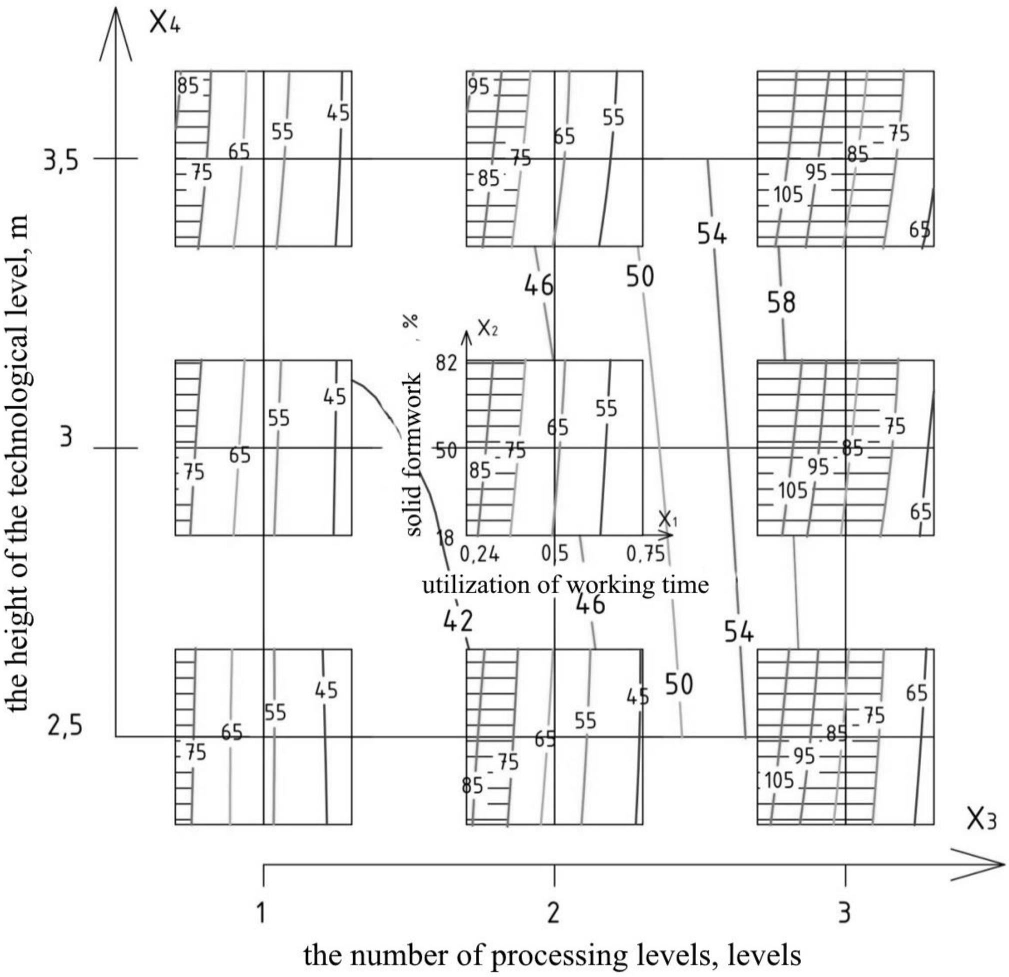

Figure 8 – "Square on the square" diagram of the influence of 4 factors on the construction duration

The research allowed determining the impact of organizational and technological solutions to effectively model the building construction. That is, the identified patterns of change in performance of construction - cost, labor intensity and duration. Zone has been found effective organizational and technical solutions for each of them on the basis of the variation indicators built construction (Figure 4, 6, 8).

The next step is looking for options with the lowest values for all indicators regarding the effectiveness of accepted boundaries.

Are effective zone with restrictions on the level of performance:

- The cost of not more than 1.8 mln UAH /in terms of building area 100 m^2;
- Labor intensity not more than 3 thousands of man-hours /in terms of building area 100 m^2;
- Duration is not more than 75 days / building area in terms of 100 m^2.

In this study, combined chart indicators building efficiency to determine the zones of effective organizational and technological solutions are presented (Fig. 9).

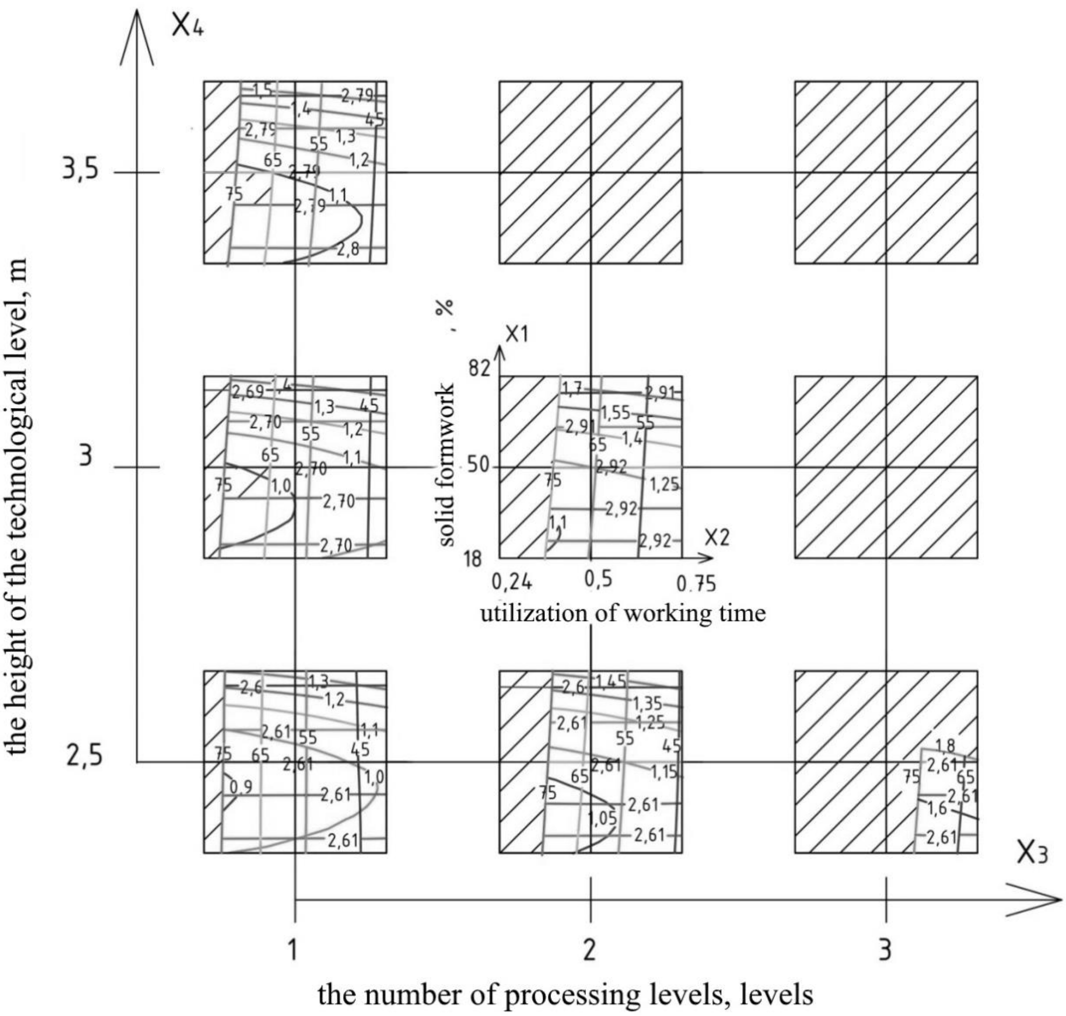

Figure 9 – Combined diagram of construction indicators for determination of the optimal organizational and technological solutions

Analyzing the chart (Fig. 9), it can be noted that the most effective are the 1 and the 2-level home at the technological level height of 2.5 to 3.5 m under the condition that the coefficient of working time is greater than the minimum (> 0, 24). For efficient construction models in all cases, better use of capacity utilization of working time, that is, to change the number of working hours, due to the increase in working hours and the introduction of shifts.

For optimal performance of construction it is possible to use a variety of options of combinations of organizational and technological solutions.

For example, for the construction of a 3-layer building area optimal solutions zone several times less than the others. All the more so ineffective are 3-level house with a height of the technological level of 3 m and 3.5 m. This is due to the increased volume of work, which in turn increase both cost and complexity, and therefore the construction duration. The range of permissible values fall 3-level home with such organizational and technological solutions:

- X_1 (utilization of working time) = 0.6-0.75;
- X_2 (solid formwork) = 18-55%;
- X_3 (the number of technological levels) = 2.5 m.

In these solutions, performance indicators for the building area 100 m^2 in terms are within the range:

- S = 1.5 to 1.8 mln.UAH;
- T = 2,610 thousands of man-hours;
- F = 60 to 75 days.

With the construction of 2-level buildings to ineffective values falls theological level height of 3.5 meters. If a viewed zone efficiency in such cases, solid of the formwork (X_2) may be at any level within the selected values, i.e. from 18% to 82%, the height of the technological level of 2.5 m and 3 m, a coefficient of use of time from 0.4 to 0.75.

Based on the analysis, it was obtained for the performance in terms of building area 100 m^2 under these restrictions:

- S = from 1.75 to 1.0 mln.UAH;
- T = from 2,79 to 2,610 thousands of man-hours;
- F = 45 to 75 days.

For a 1-level buildings, as in the previous embodiments, no limitations in continuity formwork, these solutions can be effective in the range of from 18% to 82% and the technological level height in the range from 2.5 to 3.5 m, but utilization of working time is less compared to other embodiments, and may be from 0.3 to 0.75. This suggests that the optimal values of the building is possible to get without entering the special regimes of labor, that is, without a shift, but with an increase in working hours to a maximum of 1 hours with respect to the standard 40-hour work week.

As a result, on the basis of the aforementioned limitations efficiency indicators zone optimum values were obtained for the building in terms of 100 m^2:

- S = from 1.45 to 0.9 mln.UAH;
- T = from 2,910 to 2,610 thousands of man-hours;
- F = 41 to 75 days.

Thus it can be concluded that a decrease organizational factor - ratio of working time, in all levels of the considered technological factors (continuity formwork, the number of process levels and their height) construction duration starts increasing. If we consider these factors separately, the greatest impact is the number of processing levels, as at his enthusiasm immediately increased cost and complexity, and duration, respectively.

However, since there is "time utilization ratio", whereby the entered change or increases the number of working hours per day, then the quotient "number of process levels" does not exert much influence on the duration. It follows that it is appropriate to use a longer working time in the range of 0, 5, that is at least 12-hour working day. The more so that labor intensity index on the impact of this factor is absent.

As a result, as a result of the experiment, presented the studied area factor described experimental and statistical models have the area of feasible solutions, i.e. the optimum zone.

Based on diagrams (Figure 4, 6, 8, 9), the space factor within the studied parameters may vary:

- Reducing the value of 3.3 times (S_{max} = 2,921 mln. UAH when X_1 = 0.75, X_2 = 82%, 3 = X_3, X_4 = 3.5m; S_{min} = 0,877 mln. UAH when X_1 = 0.24 ; 40% = X_2, X_3 = 1, X_4 = 2.5 m);
- Reducing the complexity is 1.5 times (T_{max} = 3,973 thousands of man-hours when X_1 = 0.4 and X_2 = 18%, 3 = X_3, X_4 = 3.5 m; T_{min} = 2.603 when X_1 thousands of man-hours = 0.3, 82% = X_2, X_3 = 1, X_4 = 2.5m);
- Reducing length 3 times (P_{max} = 120 days at X_1 = 0.24, X_2 = 82%, 3 = X_3, X_4 = 3.5 m; P_{min} = 40 days at X_1 = 0.75, X_2 = 82%, X_3 = 1, X_4 = 2.5m);

The main objective of the work is choosing the most effective organizational and technological solutions of the civil buildings construction. Technology selection problems depend on the correctness of the organizational and technological solutions of the project at the initial planning stage, which directly affect the timing of the buildings construction and the quality of finished components.

After the alignment chart of the "square in square" (Figure 4, 6, 8) that reflect the influence of 4 factors (X_1 utilization of working time, X_2 solid formwork, X_3 continuity formwork the number of technological levels, X_4

process the height of the technological level), the cost, complexity and duration of the construction of such solutions are many and they are all effective. On the basis of the combined diagram in Fig. 9, where the effective area defined organizational and technical solutions presented in the Table 3 of the most effective.

Table 3 – The most effective organizational and technological solutions of the civil buildings construction

#	Organizational and technological factors				Performance indicators
	Utilization of working time	Solid form-work %	The number of technological levels, level	The height of the technological level, m	
1	0,5	18	1	3,5	1.1 mln. UAH 58 days 2,8 thousands of man-hours
2	0,37	30	2	3,0	1.1 mln. UAH 71 days 2.92 thousands of man-hours
3	0,75	33	3	2,5	1.6 mln. UAH 56 days 2.6 thousands of man-hours
4	0,28	82	1	2,5	1.3 mln. UAH 75 days 2.6 thousands of man-hours
5	0,63	80	2	2,5	1.45 mln. UAH 55 dniv 2.6 thousands of man-hours
6	0,3	40	1	2,5	0.9 mln. UAH 71 days 2.61 thousands of man-hours

Conclusions.

It should be noted that reduction of construction time and the final cost of construction products is done while reducing the complexity of work by: improving the technology of civil construction, the use of new and effective tools and devices, more effective ways of work.

The most effective walling solution are:

- Minimal value of 0.877 mln. UAH of 100 m^2 walling surface when X_1 = 0.24 (utilization of working time), X_2 = 40% (solid formwork), X_3 = 1 (the number of technological levels), X_4 = 2.5 m (the height of the technological level);
- Minimal labor input of 2,603 thousands of man-hours of 100 m^2 walling surface that is possible under combinations of factors: X_1 = 0.24 (utilization of working time), X_2 = 82% (continuity formwork), X_3 = 1 (the number of technological levels), X_4 = 2.5 m (the height of the technological level).
- Minimum duration of 40 days of 100 m^2 walling surface for values of the factors X_1 = 0.75 (utilization of working time), X_2 = 82% (solid formwork), X_3 = 1 (the number of technological levels), X_4 = 2,5 m (the height of the technological level).

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CONCLUSIONS

1. There have been done substantial research of childcare centers development in the conditions of multifunctional civil construction: the requirements and factors influencing for the childcare centers design have been systematized. The childcare centers were classified according to different features. There were proposed interconnection schemes of the main premises of the childcare centers of integrated-attached type, their functional schemes.
2. The results of experimental-statistical simulation allowed to determine the effect on the bearing capacity of the selected factors (angle of inclination of damage, depth of the damage, relative eccentricity). Despite the fact, that the character of indicator change is not trivial, the depth of the damage mostly affects the bearing capacity.
3. There was proposed the methodology for optimal indicators values definition (duration of construction, maximum and average monthly financing intensity) under varying organizational factors (working time use intensity, number of work brigades, work processes alignment) using project management software. The research showed optimal decisions under the organizational and financial constrains.
4. The research was conducted on the development of new effective solutions of the civil construction by experimental statistical modeling of construction cost, labor intensity, duration under the influence of utilization of working time, solid formwork, number of technological levels, height of the technological level.
5. The conducted research showed optimizing different aspects of multifunctional civil construction: architectural – in terms of childcare centers as part of civil building; structural – in part of bearing capacity of stone structures; organizational and technological – in terms of effective external walling structures and overall process of civil building erection.

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