The systemic approach to modeling of compact build-up development areas and planning of their renovation.

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Abstract - This paper is devoted to the development of a methodological approach to modeling of the parts of areas of cities and settlements with their representation as a system complex city planning formation (CPF) with forming of its hierarchical object structure. Object structure includes buildings, constructions, engineering and road communications located in the area and operating under ambient conditions.

It is suggested to evaluate the parts of the areas according to technical comfort which is determined by a combination of physical and moral deterioration of these areas. In accordance with this statement, a method of defining the quantitative indicators of the technical comfort of the given areas, represented as a system model of the CPF is developed.

The systemic model of decision-making on renovation of the CPF and its constituent objects is developed to enhance the level of their technical comfort.

Keywords—Compact built-up development areas, reconstruction, system complex city planning formation, technical comfort, physical depreciation, moral depreciation, Harrington Scale.

I. INTRODUCTION

In a number of cities and settlements the established condition of the compact built-up development areas including numerous buildings and constructions, branched engineering and network infrastructure, road and transport communications etc., demands reorganization and conformation in compliance with modern norms and life activity of the population of these areas. Thus, for making effective administrative as well as organizational and technological decisions on maintenance and reorganization of the compact built-up development areas including a great number of various objects, it is necessary to elaborate a system model of these compact built-up development areas as well as the bases of methodological approach to reorganization of these areas, providing comfortable conditions for accommodation and life activity of the population of these areas.

Before choosing a certain alternative of modeling of compact built-up development areas of the cities and settlements, and also development of methodological bases of decision-making on reorganization of these areas it is necessary to make a thorough analysis of specific features of the concrete city or its part. Such analysis of the reality must be made on the basis of the modern theory and contain not only statistical data, determinative, comparative to normative, dimensional, constructive, ecological, social and other factors, but also include the methodology of making effective administrative and production decisions about reconstruction of compact built-up development areas [1,2,3,4,5,6,7]. A compact built-up development area is considered as a component part of the city intended for habitation and life activity of people, according to the modern definition of a city. “A city is one of the types of social and dimensional organizations of population, arising and developing on the basis of concentration of industrial, scientific, cultural, administrative and other functions” [8]. That is why for compact built-up development areas as parts of the city or other center of population it is already not enough to be seen only in a spatial refraction as areas of land, set of buildings, constructions and streets. A compact built-up development areas as a component part of the city is a complex multilevel system with its own laws and peculiarities of existence.

II. PROBLEM FORMULATION

Realizing the system approach to existence and development of the city and its component parts it is reasonable to see the compact built-up development area as system complex city planning formation – hereinafter referred to as CPF. In the system analysis for representation of complex systems, one of which is definitely CPF, stratified representation of such systems is normally used [9]. According to this approach, the system is set by a family of models, each of which describes its behavior from the point of view of a certain abstracting level.

Originally, in the most general, fundamental understanding, at the semantic, notional level CPF is represented in philosophic or theoretical-cognitive language as a verbal description of a project or conception. Thus, system complex city planning formation (CPF) can be defined as the set of interconnected, controllable, conditioned by existing economic and material and technical potential of the given territory, spatial, architectural and building, engineering decisions of the environment of population groups (society), providing favorable conditions for habitation and life activity of people.

Introduction of the definition of CPF with formation of its structure is necessary for dynamic evaluation and analysis of different parts and elements of a modern human environment, observing interconnection of CPF components and their interaction with environment, applying system theory and system analysis for solution of the problems of functioning and elaboration of compact built-up development areas.

Thus, for further analysis of CPF and determination of possible rational lines of its development considering unavoidable contradictions between separate components it is necessary to represent the system in the language of selected scientific theory – in the form of various kinds of models which help deeper understanding and discovering of the main idea of the system – Figure 1.

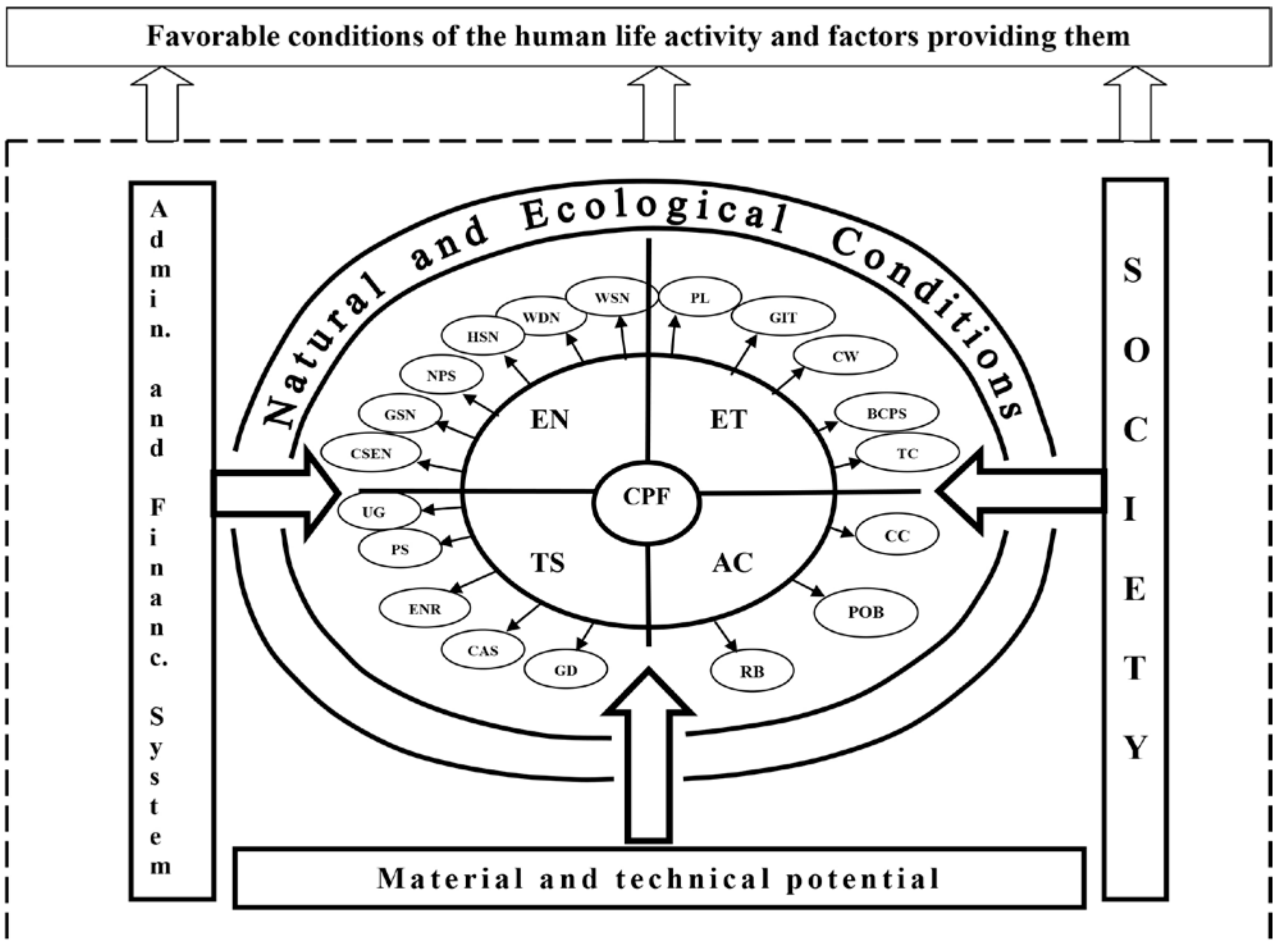


Fig 1 System complex city planning formation – CPF in the form of multilevel hierarchical system interacting with the environment.

For this purpose we make a description of the system in scientific research language of the theory of complex systems synthesis, when CPF is represented as a complex multilevel hierarchical system interacting with the environment under influence of which it is being formed.

With that, CPF is defined as the set of interconnected components – architectural and constructional (AC), engineering and network (EN), engineering and transport (ET), territorial and spatial (TS), functioning in environmental conditions for the purpose of providing the required favorable conditions for habitation and life activity of the society on the given compact built-up development area – in accordance with Figure 1.

In this case the environment implies existing natural and ecological conditions, generated material and technical potential of the certain territory, existing managing administrative and financial system and the society of the given territory.

Further, for the development of a methodological approach to making of rational organizational and technological as well as management decisions on the reconstruction of compact built-up development areas we also apply the methods of system analysis [9,10,11], which provides an opportunity to obtain accurate and science-based results.

III Problem Solution

Realizing the methods of system approach, the CPF components are considered as subsystems of the 1st level with their subsequent devision into subsystems of the 2nd level (common objects) which in turn consist of elements - private objects, making in total the subject structure of CPF – according to Figure 2.

Engineering and network component (EN) – pipeline, wire and wireless communications included into the arrangement of residential community involving networks of water supply, water drain, heat supply, gas supply, electric supply, communication and alarm, and also constructions designed for service of engineering networks and cooperation with them.

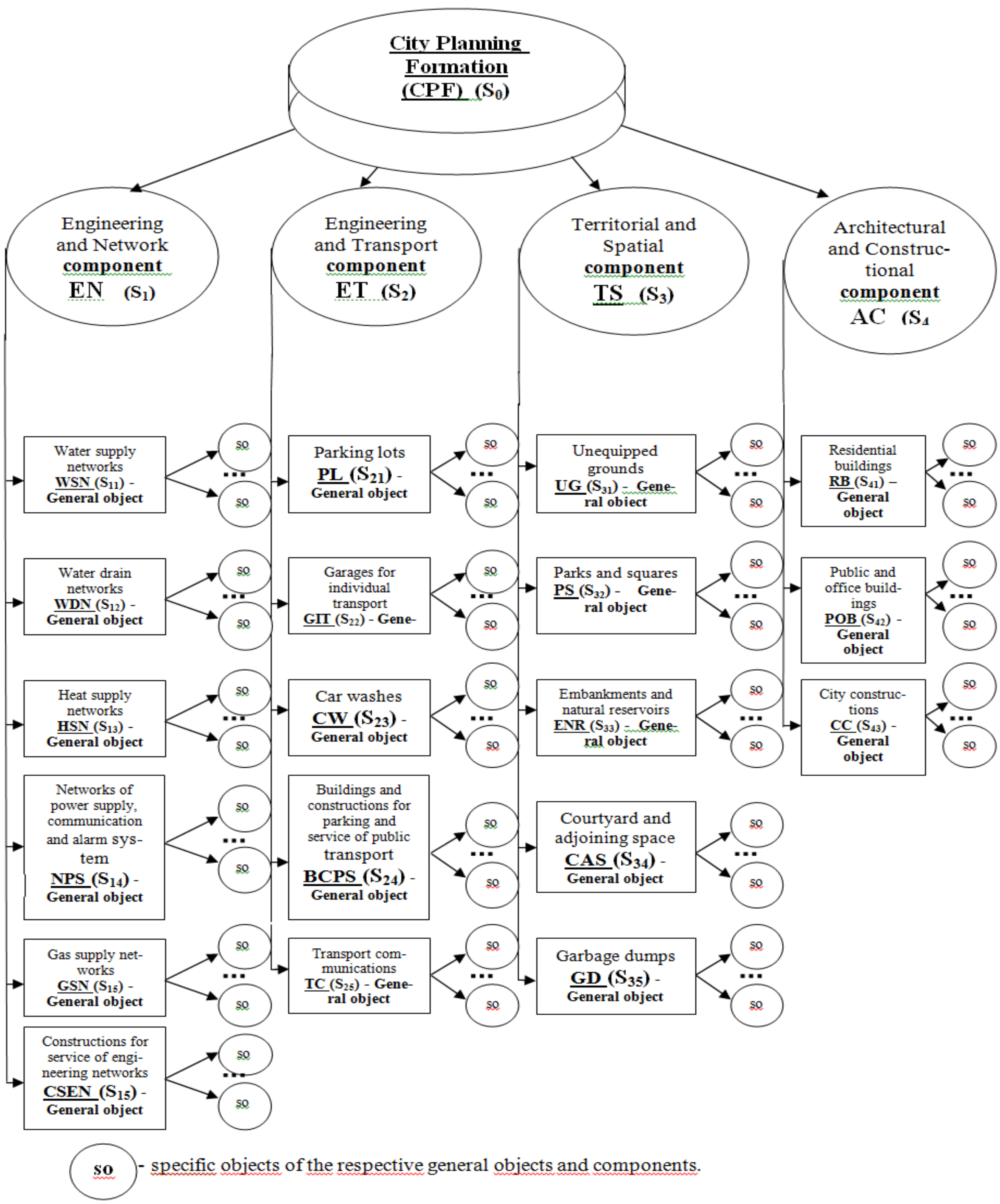


Fig.2 The objective structure of the city planning formation as a system including its components and objects

Engineering and transport component (ET) – buildings and constructions for service of public and individual transport (depots, garages, parking places, car-washing facilities, auto repair shops), transport communications (roads, bridges, trestles etc.), included into the arrangement of residential community.

Territorial and spatial component (TS) – the set of unbeautified and modified areas of land having particular functionality or being a reserve for beautification and development of the given residential community.

Architectural and constructional component (AC) – the set of residential, public and administrative buildings and constructions (monuments, stadiums, fountains etc.) located in the territory of the given residential community.

As it was already mentioned, one of the most important system design rules is that when designing the system it is required to consider its interaction with “external environment”, but the environment, in its turn, should also be regarded as a system.

In our case, the “External environment” system includes the following subsystems: Natural and ecological conditions of CPF – the set of natural components (geographical coordinates, climate, waters, soils etc.) forming natural basis of the given residential community.

Material and technical potential of CPF – the set of building materials used in the given region, industrial enterprises producing these materials and goods, building organizations, construction and mounting organizations, branches serving the construction, and also normative basis regulating construction of the CPF objects, their use and maintenance.

Administrative and financial system – the set of federal, regional, municipal authorities, regulating the relations among the CPF components as well as the relations between the whole CPF and the environment, and providing financing at the expense of the federal funds, tax and voluntary inpayments from different enterprises and organizations (industrial, commercial, banking and financial, entertainment, service etc.), including the monetary funds of the population of the given territory for development and reorganization of CPF.

CPF society - the total community of people (population) living in the territory of the given residential community or connected with it by a certain kind of activity or way of life, which is expressed by a system of stable social mutual relations.

As it was noted before, the aim of CPF functioning when interacting with environment is creation of favorable conditions for life activity of the society. At the same time it is necessary to consider the permissible level of resource expenditure. This aim as it is formulated is quite difficult to define on the number scale which makes it necessary to introduce the goal achievement efficiency indicator – or criteria – the factors for evaluation of correspondence between functioning of the system and the given result.

With regard to CPF it is reasonable to take as efficiency indicator such global factors as “comfort” (C) and “resource consuming” which in their turn depend on the particular factors.

Resource consuming – is characterized by material and technical consumption, energy consumption and labor expenditures, measured in money equivalent, for providing current functioning or rearrangement of the habitation and life activity environment in order to achieve the required level of its comfort.

Comfort, in its most general form, remains at the level of sociological understanding and meets the following definition - the convenience of living environment and life activity [5].

According to the definition of comfort, all components and objects included in the CPF have a direct or indirect impact on the convenience of living environment and life activity of the society.

The Academician of the Russian Academy of Architecture and Building Sciences A.V.Stepanov states: "Attempts of European sociologists to define the concept of "comfort" and somehow normalize it in order to use it for evaluation of the home quality, were unsuccessful" [12].

Quantitative measurement of C is very difficult both because of the lack of appropriate methodology and because of the ambiguous, subjective attitudes of different groups of population to this concept.

In the paper [13], with reference to social studies, the qualitative macro criterion of C is stated: "it is convenient to live in a beautiful house," which in its turn, is characterized by the parameters of a residential building, including its engineering equipment and architectural and artistic expression; the habitat parameters, i.e. parameters of the construction and settlement areas; the parameters of durability and reliability of the given building.

Therefore, the main problem is to clarify the concept C and to define its evaluation criteria. To solve this problem it is advisable to apply the methods of system analysis which include representation of the modern living environment and life activity of the population i.e. compact build-up development areas in a form of system complex city planning formations (CPF) in accordance with Figures 1 and 2.

According to the most general definition, comfort can be represented as a set of technical comfort (TC) and social comfort (SC) - Figure 3.

The CPF technical comfort is the convenience of technical construction of the habitat of society, evaluated by its degree of compliance with sanitary and hygienic standards, regulations and safety standards of this habitat and other parameters which are set, if necessary, by qualified specialists - experts.

Social comfort is the convenience of the habitat of society, evaluated as a degree of perception of technical comfort by the society.

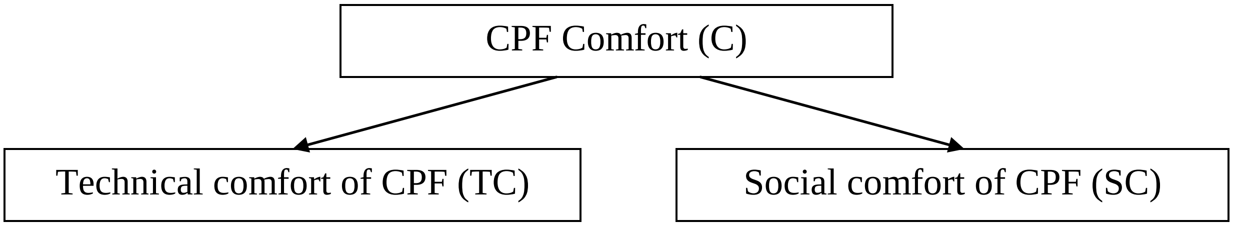


Fig.3 The CPF comfort as a set of technical and social comfort.

Thus, SC is to a considerable degree dictated by the TC level because regulations, standards and other normative documents are developed on the basis of objective indicators, taking into account the vital needs of society. At that it is obvious that the degree of decrease and increase of SC is monotonically connected to the degree of decrease and increase of TC.

That is, the key factor defining the CPF comfort as a set of TC and SC is the convenience of technical construction of the habitat of society of the CPF - TC.

Formally, the above arguments can be written in the following form:

$$C = f(TC, SC = \varphi(TC)) \quad (1)$$

In accordance with this, then we consider only TC of CPF as a major factor in determining the overall comfort of CPF.

In general:

$$ТК = ИК - \Delta \quad (2)$$

where *IC* is the ideal, maximum possible comfort of CPF assumed as 1 or 100%,

Δ - is a deviation of the real TC of CPF from the ideal one which is defined as the total characteristics of physical depreciation (Ph) and moral depreciation (M).

$$\Delta = \Psi \text{ (M, Ph)\%} \quad (3)$$

Thus, the composition and structure of the CPF efficiency indicators will appear as shown in Figure 4.

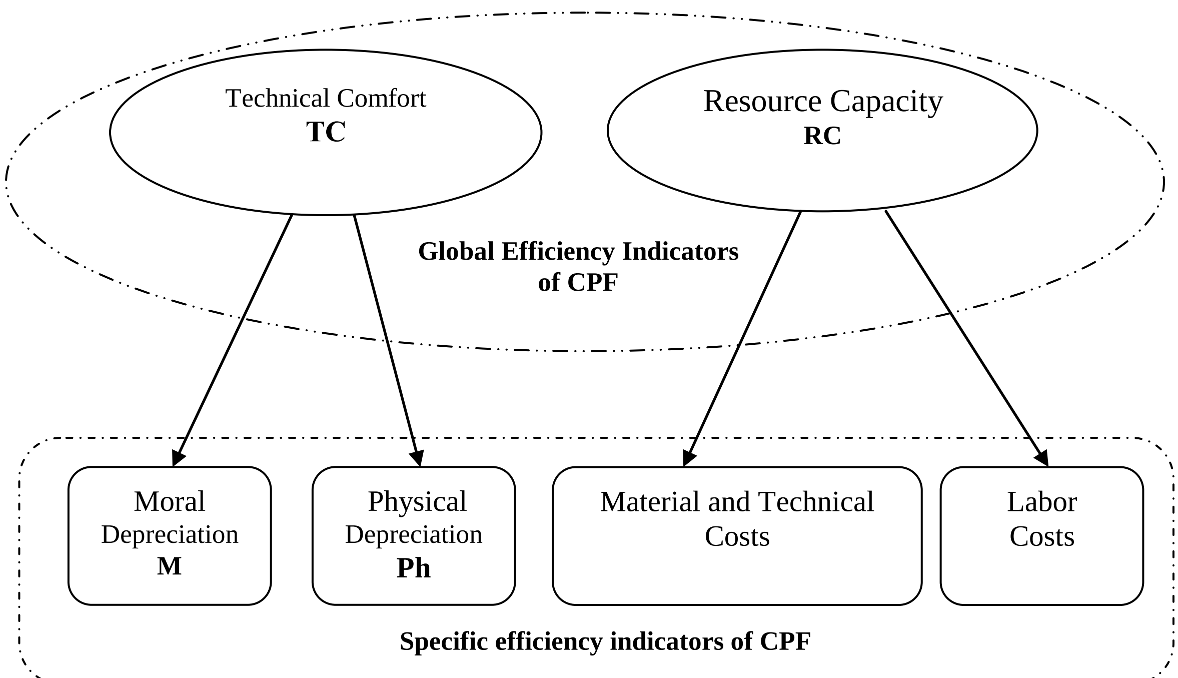


Fig.4 Composition and structure of the CPF efficiency indicators.

With this approach, technical comfort of CPF, its components and objects can be characterized by their moral (M) and physical (Ph) depreciation which are calculated according to the methods described in [6].

Indeed, a modern person (or society) will feel most comfortable living in a certain area of the city - CPF (buildings, engineering equipment, transport infrastructure, etc.) built in accordance with modern environmental, operational, architectural and other requirements, i.e. with minimal moral depreciation, and also providing the reliability, integrity and security of all CPF components (buildings, engineering equipment, transport infrastructure, etc.), i.e. in the absence of their physical depreciation.

That is, the lower the total characteristics of physical and moral depreciation of the CPF and its components is, the higher their TC is, and vice versa:

$$TC = [1 - \Psi (Ph, M)] \cdot 100\%, \qquad (4)$$

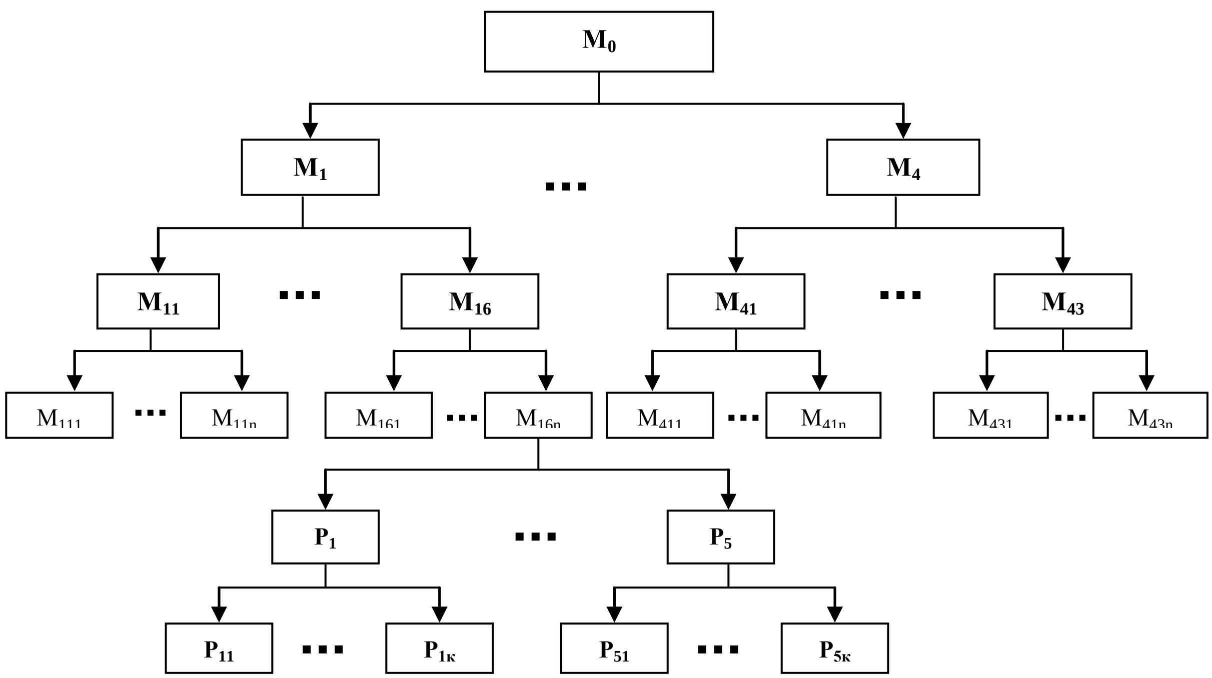
where Ph is an integral indicator of physical depreciation of CPF;

M is an integral indicator of moral depreciation of CPF

In accordance with the object structure (Figure 2), using the theory of multilevel hierarchical systems [9], the integral indicators of Ph and M of all CPF are represented as a set of integral indicators of Ph and M of its components. Similarly, the integral indicators of Ph and M of the components are represented as a set of integral indicators of Ph and M of the general objects included in it, and integral indicators of Ph and M of the general objects are represented as a set of integral indicators of Ph and M of the private objects included in it.

Based on the above statements, the CPF moral depreciation indicator tree will look as shown in Figure 5, and the CPF physical depreciation indicator tree will look as shown in Figure 6.

The essence of the method of evaluating moral and physical depreciation of the CPF, its components, general and specific objects is described in detail in [6].

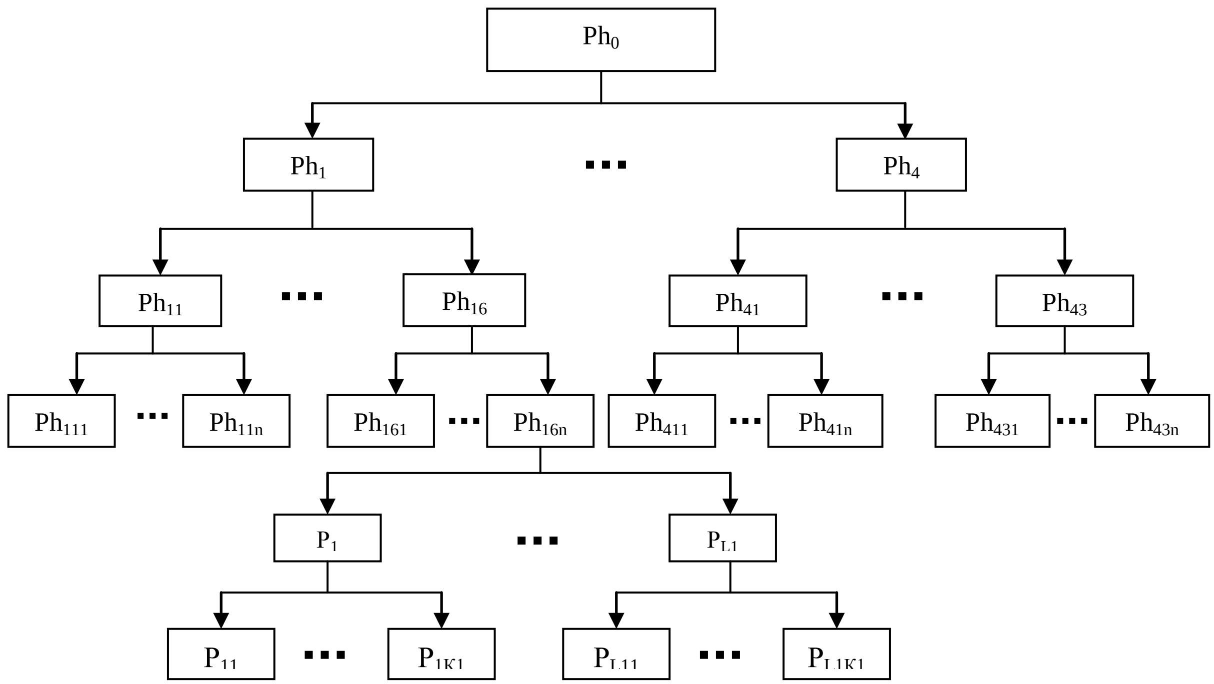


P_i, i = $\overline{1,5}$ - general indicators of moral depreciation of specific objects;

$P_{iк}$, i = $\overline{1,5}$, к = $\overline{1, к1}$ - specific indicators of moral depreciation of specific objects;

M – integral indicators of moral depreciation of CPF, its components, general and specific objects

Fig. 5 CPF moral depreciation indicator tree



P_l, $l = \overline{1,L1}$ - indicators of physical depreciation of the constructions or elements of specific objects;

$P_{l\kappa}$, $l = \overline{1,L1}$, $\kappa = \overline{1,K1}$ - indicators of physical depreciation of separate parts of the constructions or elements of specific objects;

Ph – integral indicators of physical depreciation of CPF, its components, general and specific objects.

Fig. 6 CPF physical depreciation indicator tree.

To determine the technical comfort of CPF and its components in accordance with the formula (4), the folding of these indicators in the total integral indicator of physical and moral depreciation of specific objects, general objects, CPF components and CPF itself should be performed by the the technique of folding the indicators described in [6].

At that, it is necessary to consider that the total integral indicator combines 2 indicators different in its meaningful essence: physical and moral depreciation.

Thus, a residential or public building with the high moral depreciation (of 40% -60% and more) usually does not carry immediate danger to humans in the nearest feature, and therefore it can be used with certain restrictions. Whereas buildings with the real physical depreciation (over 40%), are really dangerous to the people living in them and are subject to immediate overhaul or reconstruction.

Therefore, while drawing the circular chart [6] to determine the TC of a specific or general object (residential building) in case of its physical depreciation of 40% or more, the radius of the sector, corresponding to the physical depreciation in a circular chart, should be taken as maximum, equal to 1 or 100% of conditional physical depreciation, and be evaluated on the Harrington scale [6] as "very bad". The same principle is appropriate to apply in determining the total indicator of TC of other objects, components and CPF itself - in accordance with Figure 2 - if the value of their physical depreciation is over 40%, the radius of the sector should also be taken as maximum, equal to 1 and be evaluated on the Harrington scale (Table 1) as "very bad".

Table 1. Characteristics of the CPF state according to its TC values.

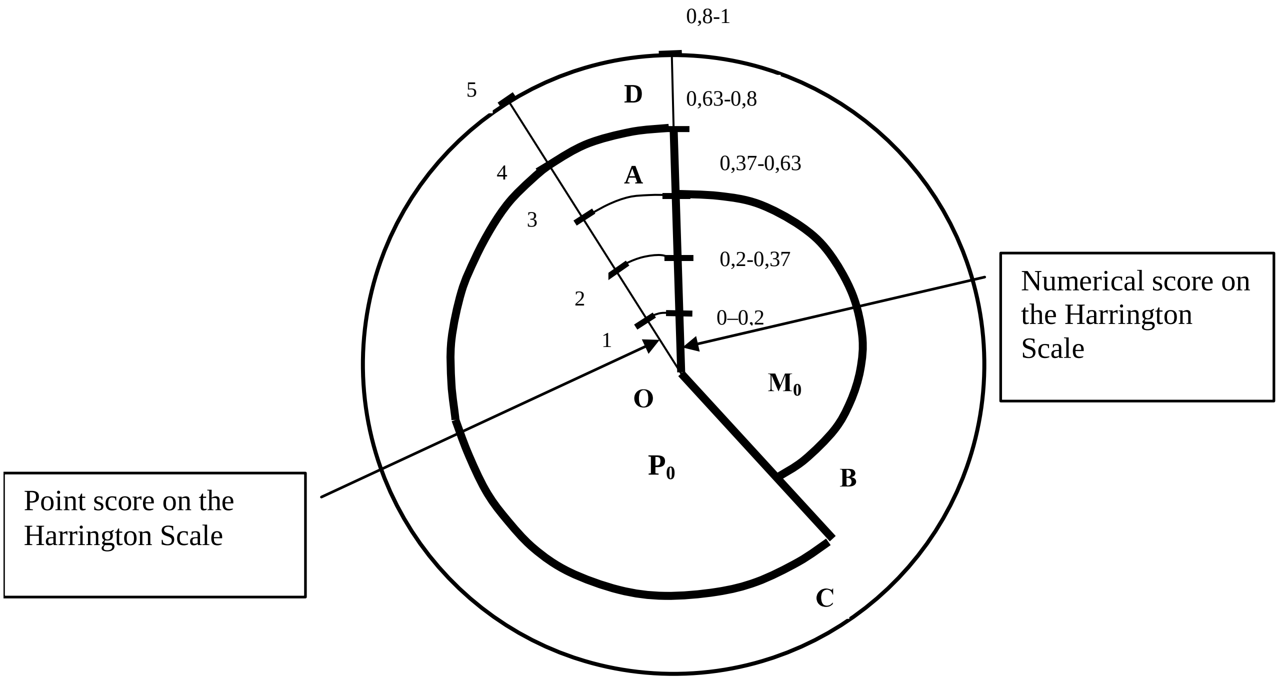
Verbal score	**Point score**	**Numerical score**
Very high – “excellent”	5	0,8 - 1
High – “good”	4	0,63 – 0,8
Average – “satisfactory”	3	0,37 – 0,63
Low – “bad”	2	0,2 – 0,37
Very low – “very bad”	1	0 – 0,2

Indeed, the physical depreciation of 40% and more means for and object, component or CPF itself the corresponding loss of its initial qualities, which poses a risk to life and health of a human and (or) environment.

This implies that when evaluating the physical depreciation on the basis of the Harrington scale (%) of the actual physical depreciation will always correspond to the percentage M = 2,5N (%) of conditional physical depreciation.

Figure 7 shows an example of calculating TC - an indicator of technical comfort of CPF. Let the previously calculated value of the real integral indicator of physical depreciation

P_0 = 30%, which corresponds to 75% of conditional physical depreciation, and hence to the point score of 4, the numerical score of 0,8 and the verbal score of "bad" on the Harrington scale.



P_0 – the integral indicator of physical depreciation of the CPF in a form of an area of the corresponding sector S_{COD};
M_0 – the integral indicator of moral depreciation of the CPF in a form of an area of the corresponding sector S_{AOB}.

Fig. 7 Unit circular chart with the Harrington scale for displaying the total integral indicator of physical and moral depreciation of the CPF.

Let the previously determined value of the integral indicator of moral depreciation of CPF - M_0 = 62%, which corresponds to the point score of 3, the numerical score of 0.63 and the verbal score of "satisfactory" - also on the Harrington scale. At that, the "weight" of the indicator P_0 – the opening angle of the corresponding sector - will be β_{P0} = 0,625, and the weight of the indicator M_0 – also the opening angle of the corresponding sector – will be β_{M0} = 0,375. Then, to determine the integral indicator of the CPF comfort - C, we define the total characteristics of physical and moral depreciation of the CPF - f (Ph, M) as the area of the figure S_{ABCD}, representing the sum of the areas of relevant sectors, multiplied by the factor 1/π.

$$S_{ABCD} = (S_{AOB} + S_{COD}) \cdot 1/\pi \qquad (5)$$

$$S_{AOB} = \pi \cdot r^2 \cdot 0{,}375 = \pi \cdot 0{,}63^2 \cdot 0{,}375 = 0{,}15 \cdot \pi ;$$
$$S_{COD} = \pi \cdot r^2 \cdot 0{,}625 = \pi \cdot 0.8^2 \cdot 0{,}625 = 0{,}4 \cdot \pi;$$
$$S_{ABCD} = \pi \cdot (0{,}15 + 0{,}4) \cdot 1/\pi = 0{,}55.$$

According to formula 4, we have TC = (1 - 0,55) • 100% = 45%, that corresponds to the verbal score of "satisfactory" on the Harrington scale, and to the score of 3 points on the numerical scale.

On the basis of technical comfort of the considered CPF, calculated in this way, we establish the actions which ensure its transition to the specified state: "satisfactory", "good" or "excellent."

Possible variants of actions concerning further functioning or reconstruction of CPF, including all its material components and subsystems after rating them by corresponding efficiency indicators, are as follows: 1. Maintenance of service properties – current repair. 2. Repair of the separate objects, areas and elements. 3. Capital repair. 4. Reconstruction and modernization. 5. Construction of additional objects, areas and elements. 6. Demolition and dismantling of old objects, areas and elements with construction of new ones and others.

Let us look at the structure and components of the concept “action” with respect to the given variants in accordance with fig. 8.

Subject of action – are organizations and enterprises directly implementing examination, architectural and building projecting and CPF reconstruction works. Object of action – are CPF components which are liable to reorganization – architectural and constructional component (AC), engineering and transport component (ET), territorial and spatial component (TS), engineering and network component (EN) – also including their constituent subsystems and elements.

Aim of action – is the reorganization of CPF, including its components, with achievement of the established level of comfort at the minimal resource expenses.

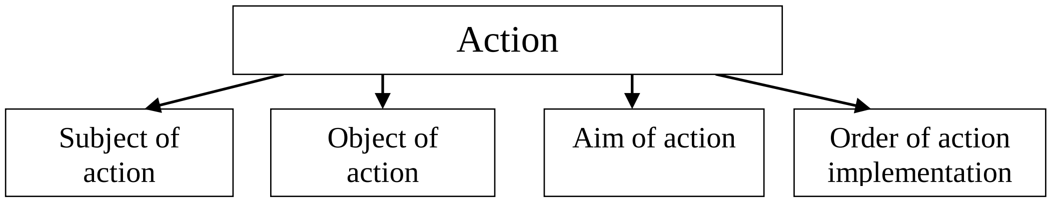


Fig. 8 Structure of the concept "action".

Order of action implementation – is the complex of technical and technological solutions, providing the achievement of the set aim.

Thus, the system of decision-making on reorganization of CPF has 3 levels of specification of description – or strata – according to the terminology [9] accepted in the system analysis as shown in the fig. 9.

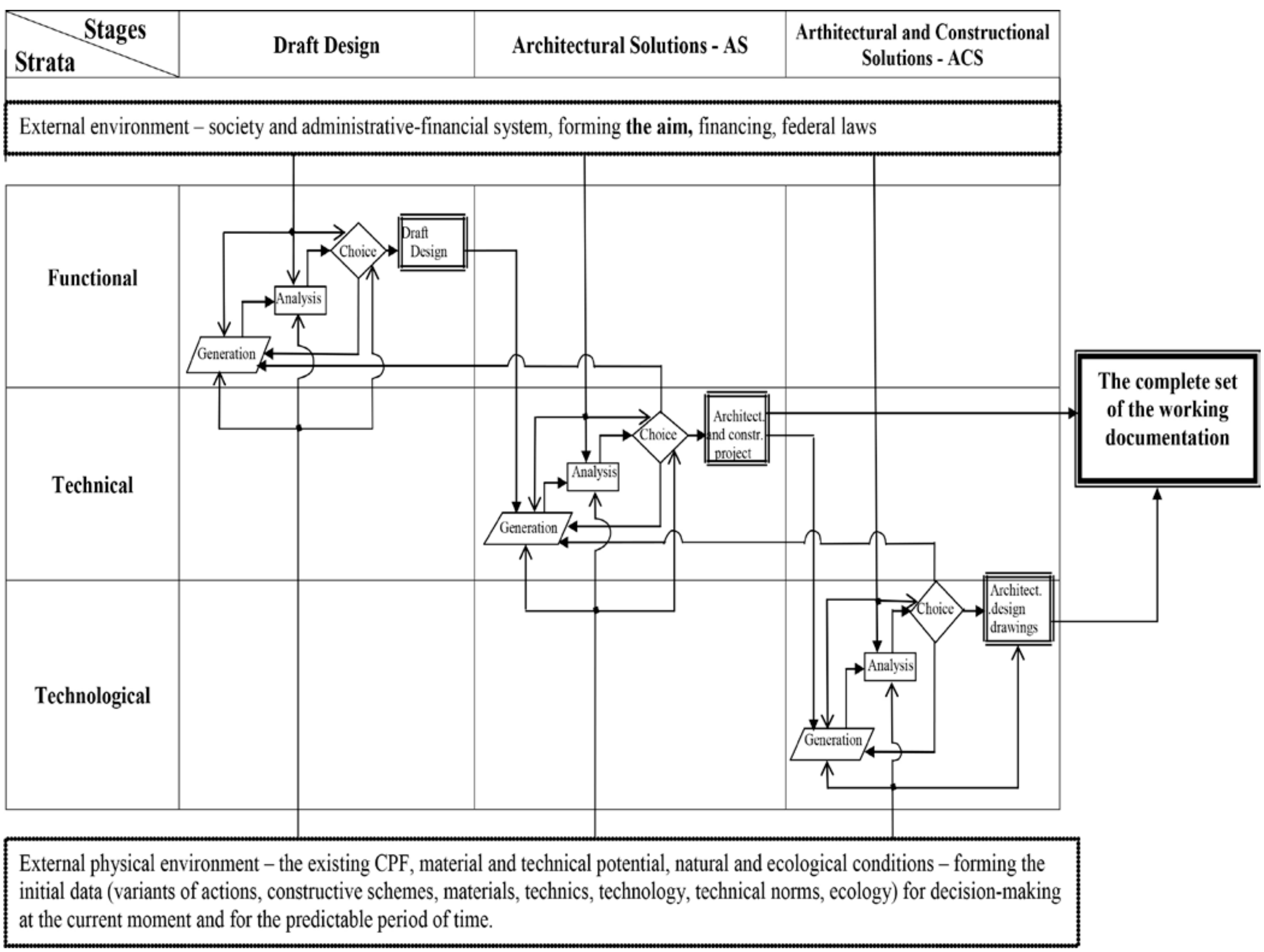


Fig. 9 Technological scheme of decision-making on reorganization of compact built-up development areas

Concepts – such as subject, object, aim of action are included into the first level of specification of description of decisions – functional stratum, where the decisions (R1) are made on the establishment of the concrete content of these concepts on all the components and subsystems of CPF.

On the basis of the first functional stratum, a different variant of actions on reorganization or functioning can be chosen for the different CPF components depending on the established efficiency indicators, such as comfort and resource intensity and, in the general case, the quantity of diverse combinations of variants can turn out to be very considerable.

For example, for the territorial and spatial component (TS) the variant of actions such as «construction of additional objects, sites and elements» can be accepted, for engineering and network component (EN) it can be "general overhaul", for engineering and transport component (ET) and architectural and constructional component (AC) – «reconstruction and modernization».

The next concept - order of action implementation has two levels of specification of description (two strata) - technical and technological.

The second level of specification of description of decisions is technical level, where the general technical decisions (R_2) on achievement of the chosen aims are formed. For example, the "reconstruction and modernization" decision on architectural and constructional component, accepted in the functional stratum, in its turn, in the technical stratum can be realized by the development of design decisions on superstructure of floors, extension of additional sections, change of inner layout, etc.

The third level of specification of description of decisions is technological - that is definition of thorough and detailed design and technological decisions (R_3), providing the implementation of technical decisions.

Thus, generally, the values of the global efficiency indicators such as technical comfort (TC) and «resource intensity» (RI) depend on the chosen decisions R_1, R_2, R_3. In this case, the problem of CPF synthesis consists in definition of such decisions on the functional, technical and technological strata which provide minimal resource expenses for achievement of the established comfort.

Formally the problem is put down as follows.

To find

$$(R_1, R_2, R_3)optimal = \underset{<R_1, R_2, R_3>}{\text{arq min}}\, RI\,(R_1, R_2, R_3) \qquad (6)$$

At the restrictions

$TC\,(R_1, R_2, R_3) \geq TC_{required}$

$R_1 Є\ RD_1$ - set of admissible actions.

$R_2 Є\ RD_2$ - set of admissible technical decisions.

$R_3\ ЄRD_3$ - set of admissible technological decisions.

At an estimation of CPF condition as a system, its global and private efficiency indicators cannot be expressed in the form of analytical dependences on the considered variables (R_1, R_2, R_3), that would allow to carry out the forecast of the developments and to introduce recommendations on functioning and reorganization of compact built-up development areas on the basis of corresponding mathematical models. To solve the problems of synthesis of complex systems of this kind, nowadays multistage technological schemes of their solution are developed [9].

At that, the decision-making process at any stratum is divided into 3 subprocesses: generation of variants, estimation of variants - analysis and choice. These subprocesses are considered as decision-making layers.

On the "generation" layer operations on formation of admissible variants of actions on reorganization of each component and corresponding subsystems of CPF, technical decisions on realization of each chosen action, technological decisions on realization of each chosen technical decision, are realized.

On the "analysis" layer reception of quantitative and qualitative values of the indicators characterizing CPF efficiency on a set of chosen admissible variants of actions, and chosen admissible variants of technical and technological decisions, is carried out.

The "choice" layer includes operations of the search of preferences (in the meaning of set criteria) of action variants, technical and technological decisions, which determine rational composition and structure of CPF, and also values of component, subsystem and element characteristics.

The technology of CPF synthesis - as determination of variants of actions and decisions on functional, technical and technological strata - consists in time analysis of the set of formal and heuristic operations on compromise decision-making on substantiation of CPF structure for the purpose of receiving the necessary set of working documentation, regulating its reorganization.

At the first stage - that is the draft design of reorganization of a compact built-up development area – the functions (aims) of necessary actions concerning each component and object of CPF are defined.

At the second stage - architectural and building project – technical decisions which are necessary for achieving the generated aims are determined.

At the third stage – concrete working drawings and documentation for direct implementation of reorganization – the detailed constructive and technological decisions, realizing the chosen technical decisions, are defined.

As a result, the technological scheme of decision-making on reorganization of compact built-up development areas will look as it appears in the picture 5.

Thus, the offered methodology allows to form a great number of admissible variants of actions on reorganization of CPF, as well as to estimate the efficiency of each variant by the series of basic indicators and to make a reasonable choice of an expedient variant by the accepted criteria.

In the Figure 9 there is an example of determining the variants of actions on reorganization of the CPF object – "Residential building" – with specification on 3 strata, in assumption that by the set criterion – minimal resource expenses at the given comfort – the action such as «Reconstruction and modernization», and technical decisions such as «Superstructure of floors» and «Built-in framework» are chosen.

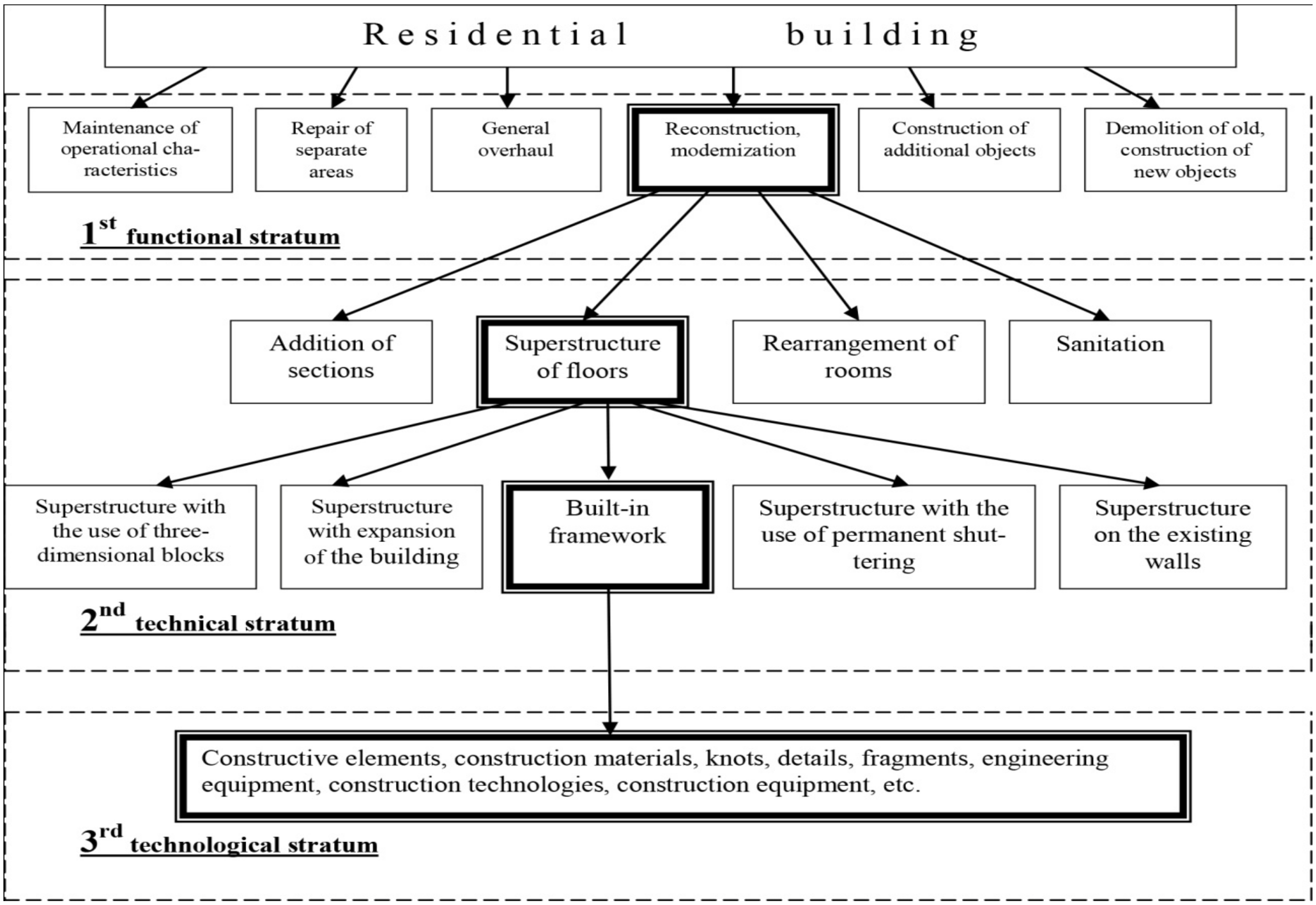


Figure 9. - Example of determination of the action variants with specification on 3 strata on reorganization of the CPF object - "Residential building".

IV CONCLUSION

1. The system model of compact build-up development areas on the epistemological level with verbal description and forming of the object structure in the form of system complex city planning formation (CPF) is developed.

2. The efficiency indicators of functioning and renovation of CPF, i.e. technical comfort and resource capacity, are proposed.

3. A possibility of evaluation of the technical comfort of CPF and its components by the set of indicators of physical and moral depreciation of CPF and its components is proposed.

4. For the first time the methodological approach to determining the qualitative indicators of technical comfort of CPF and its components is developed. It contains the hierarchical representation of indicators of their physical and moral depreciation, the determination of their numerical values with their subsequent folding while moving up the indicator tree using a unit circular chart combined with the Harrington scale.

5. The systemic approach to decision-making on renovation of CPF in a form of the models of "generation - analysis - choice" is developed for determining the action variants, technical and technological solutions.

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