# Methodological approach to the substantiation of the form of compact build-up development areas with the aim of their renovation.

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Abstract: - This paper proposes a methodological approach to the establishment of a rational form of the parts of compact build-up development areas intended for reconstruction in accordance with modern requirements. Modernization of the parts of these areas involves renovation of the entire complex of objects located in these areas and requiring reconstruction. These objects include: residential and public buildings, engineering networks, road infrastructure, parks, squares and others.
The basis of substantiation of the form of the parts of urban areas for their reconstruction is the principle of similarity of the indicators of physical and moral depreciation, the number of floors in the residential buildings located in these areas and meant for renovation. This is due to the fact that this principle, on the one hand, realizes one of the main needs of society that is safe and comfortable residential buildings, and on the other hand contributes to typification of constructive and organizational and technological decisions made during the planning of the renovation of residential buildings at the given part of the urban area.
The methodological approach includes a combination of the following methods: model representation of compact build-up development areas as a system - city planning formations (CPF); determination of physical and moral depreciation of the CPF and its components; method of generating variants of CPF; method of evaluating the effectiveness of the selected variants; method of selecting rational variants of CPF from the generated ones.

*Key-Words:* methodological approach; form; compact build-up development areas; city planning formation (CPF); renovation; moral depreciation; physical depreciation; expert method; Harrington scale.

## 1 Introduction

Progressive development of the human society stipulates the need for improvement and transformation of the environment providing the possibility of social life activity in ecologically clean, "green" territories, including the buildings with higher energy efficiency and comfort [1, 2, 3]. One of the significant forms of the modern human environment are the mass housing development areas (CBDA) involving a complex of buildings and constructions intended for creation of worthy or acceptable living conditions for people in cities and housing areas.

In the modern city areas there are a number of growing problems caused by inevitable physical and moral depreciation of buildings and constructions, including historical and architectural monuments, of certain engineering and road infrastructure, parks, public gardens and other objects [4, 5, 6].

Moral depreciation is a gradual lagging of consumer properties of the previously created urban assets (buildings, constructions, engineering equipment, infrastructure, etc.) comparing to the advances of modern environmental, operational, architectural and technical level in this area.

Physical depreciation is a gradual loss of the original quality of urban assets as a result of their natural aging process.

Nowadays the depreciation of the fixed assets of the Russian housing and communal services system is about 60%; in certain regions it reaches 80%. Thus, the current state of the CBDA proves the need for their urgent modernization and renovation.

The majority of the researchers dealing with issues of planning of the reconstruction of an urban environment emphasize the necessity of reorganization not only separate objects (houses, engineering networks, highways, parks, etc., but also their coupled combination in the form of certain city blocks, complexes or the whole area of housing estates [7,8]. For planning such reorganization of the living environment, with coordination of development and renovation of all its components and parts – buildings, engineering networks, roads, etc., it is reasonable to apply the systematic

approach [9, 10, 11] which allows one to create effective models of territories of the modern human residence.

At the same time the analysis of the papers in the field shows that the recommendations for a systematic choice of the form and concrete sites of CBDA providing rational resource consumption for CBDA renovation and reconstruction are insufficiently developed.

## 2 Problem Formulation

The compact built development area, i.e. a modern environment of residence and human life activity, could be represented in a system form as a systematic complex city-planning formation (CPF) [11]. The systematic complex city-planning formation is a set of the interconnected and controllable spatial, architectural and engineering solutions of the living environment of population groups (society), providing the certain favourable conditions for habitation and human life activity due to existing historical, economical and material-and-technical potential of the given territory.

The detailed subject structure of CPF is given in Figure 1. For effective planning of the CPF reconstruction , it is necessary also to define and characterize its form and structure which are subject to modernization and renovation.

For this purpose, according to the methodology stated in [11], it is necessary to (1) develop the method of determination of physical and moral depreciation of the CPF and its components; (2) generate the CPF variants with specification of their content and establishment of the corresponding form within an urban development area; (3) estimate the efficiency of the selected variants, and (4) select the rational CPF variant from the generated ones.

## 3 Problem Solution

Developing an effective method for estimating moral depreciation of the CPF and its components caused by the need to make reasonable organizational, managerial, financial, and technological decisions on the reconstruction of CBDA and establishing the sequence of production of reconstructive work.

The reliable estimation of moral depreciation of the city assets represented by CPF, its components, general and specific objects, is a challenging task due to the lack of normative methods or methods of a differenty type, considering specificity of the CPF and its components and availability of constantly improving requirements for these assets (buildings, engineering infrastructure, parks, roads, etc.).

The proposed approach to estimation of moral depreciation of general and specific objects, CPF components and CPF as a whole is based on the generally accepted definition of moral depreciation of the city assets, reliable, proven, effective methods of system analysis and expert evaluations [9, 10, 12].

In accordance with the object structure (Figure 1) an integral indicator (II) of the whole CPF is represented as a set of II of moral depreciation of its components, while II of moral depreciation of the components and general objects of the CPF are represented as a set of II of moral depreciation of their hierarchically underlying components or elements. The indicator tree of moral depreciation of CPF and its components is shown in Figure 2.

Evaluation of moral depreciation of the whole CPF should begin with evaluation of moral depreciation of specific objects as elements of the underlying level of the moral depreciation indicator tree.

For example, as shown in Figure 1, for a certain CPF ($S_0$) with architectural and construction component AC ($S_4$) which includes the general object - residential buildings - RB ($S_{41}$), evaluation of moral depreciation begins with evaluation of moral depreciation of the specific object - each separate concrete residential building, which is part of the general object.

It is advisable to evaluate moral depreciation of specific objects by a range of general indicators. As general let us select the following indicators of moral depreciation: lag in constructive and space-planning parameters ($P_1$); lag in sanitary and environmental parameters ($P_2$); lag in engineering parameters ($P_3$); lag in architectural and artistic parameters ($P_4$); lag in social and infrastructural parameters ($P_5$).

To characterize the moral depreciation of certain specific CPF objects not all of these indicators can be applied, but a set of them selected in particular for a specific object can provide reliable evaluation of moral depreciation of the respective object.

Each of these general indicators of moral depreciation for a concrete specific CPF object as a rule is divided into a number of particular indicators (Pik, $i = \overline{1,5}$, $k = 1,,\overline{1,к1}$) most fully characterizing the individual manifestations of a general indicator of moral depreciation of the specific object. For example, a lag in engineering parameters ($P_3$) of the specific object - every single concrete residential building which is a part of the general

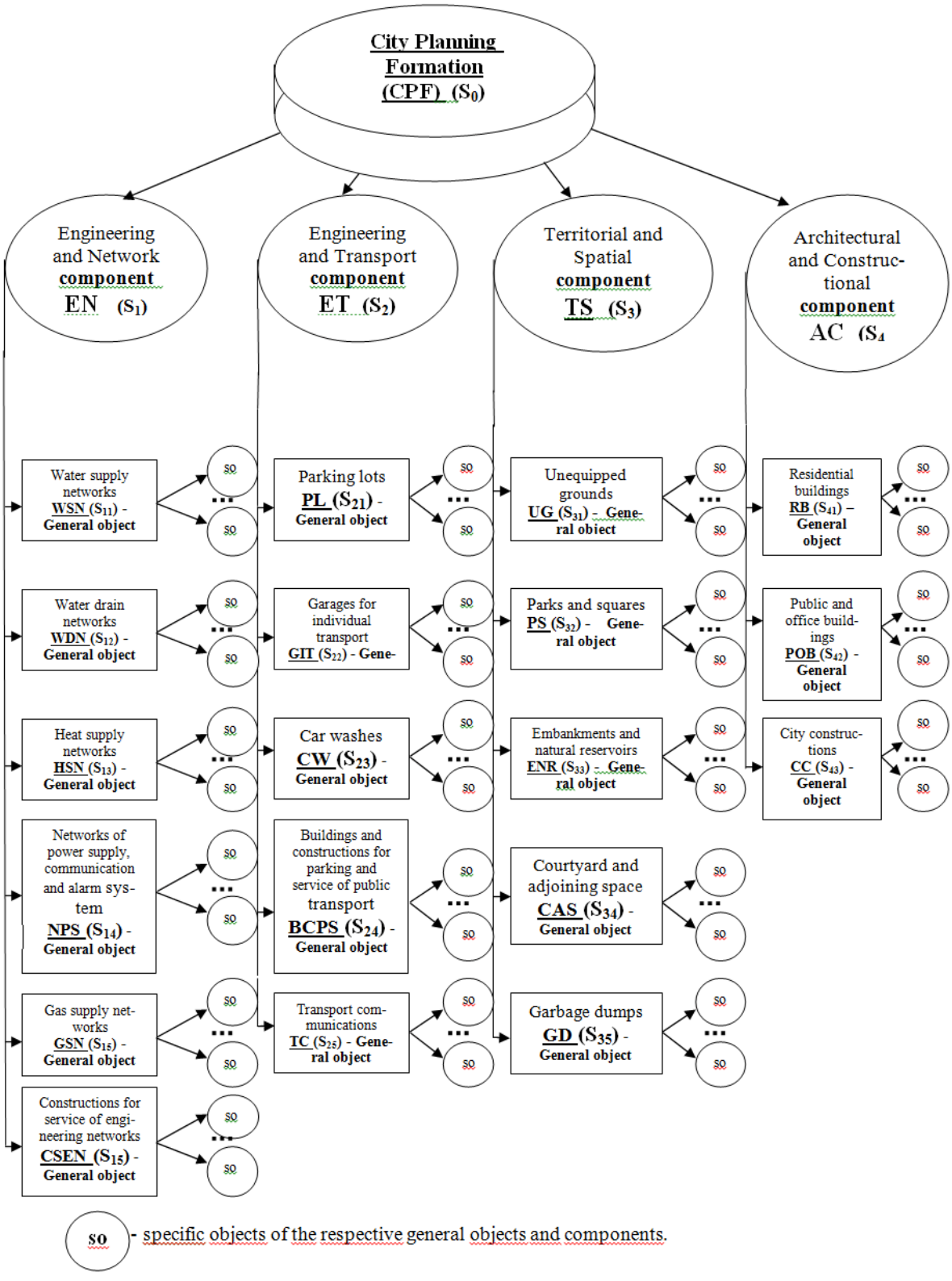
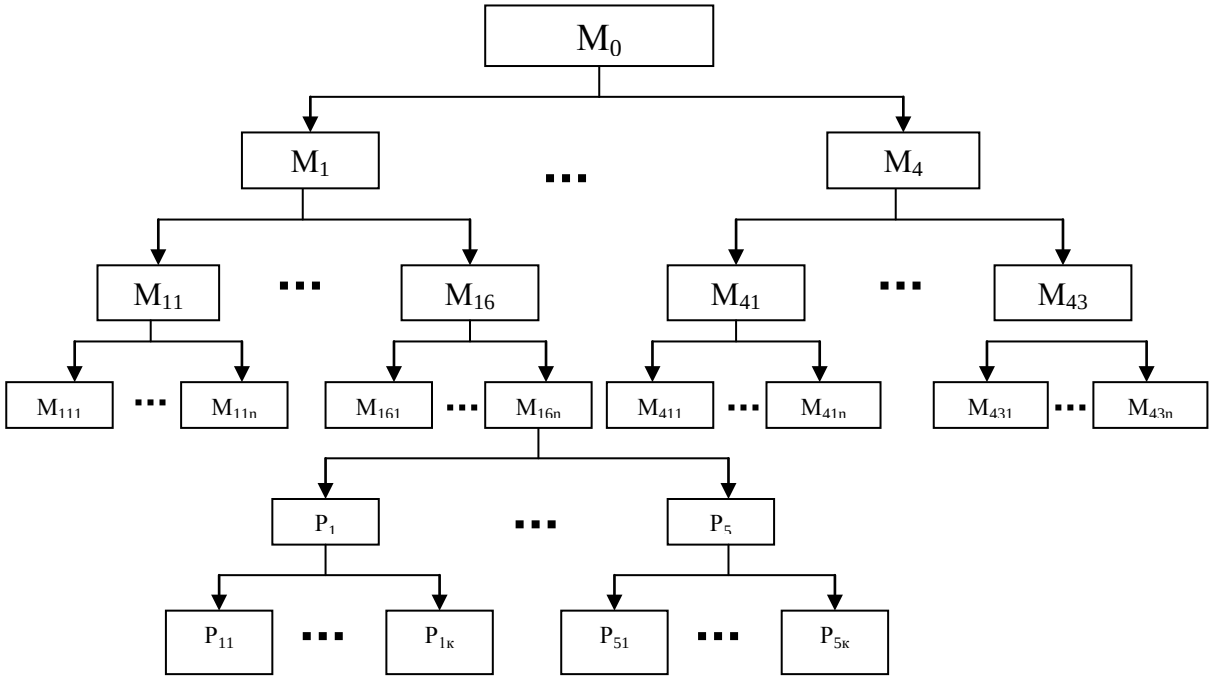



Fig. 1. The objective structure of the city planning formation as a system including its components and objects.




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

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

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

Fig. 2. The indicator tree of moral depreciation of CPF

object - RB ($S_{41}$) can be estimated by the following particular indicators: content of engineering equipment in the building ($P_{31}$); degree of use of modern materials for engineering equipment ($P_{32}$); degree of use of modern technical solutions for engineering equipment ($P_{33}$)

It is advisable to characterize each individual indicator of moral depreciation by a set of grades which are measured in points - from 1 to 5. A rating of 5 points - a very high degree of moral depreciation - corresponds to the maximum depreciation, and a rating of 1 point - a very low degree of moral depreciation - is the minimum moral depreciation or its absence.

Gradation values are determined by the regulations or by an expert method. In the absence of clear standards the gradation values are determined by an expert method. For example, by an expert method the gradation is assigned to a particular indicators such as the actual height of the residential buildings, which affects the compliance of the space planning solutions of the building (general indicator - $P_1$) with modern requirements.

This particular indicator of moral depreciation can be evaluated by a group of qualified experts by using standard methods [12].

For receiving the gradations of moral depreciation established normatively or with the help of experts, and processing them by quantitative methods it is advisable to use verbal and numerical scales, which include meaningfully described names of their gradations and corresponding numerical values or ranges of numerical values. A widespread example of such a scale is verbal numerical Harrington scale [13]. In our case, a slightly modified version of Harrington scale with the change of verbal characteristics of numerical scores (gradations) to the opposite is used to evaluate moral depreciation - Table 1. Each gradation of the verbal numerical scale corresponds to an interval of numerical values in the interval (0-1) and a corresponding linguistic definition.

Tab. 1 The Harrington Scale for the estimation of the indicators of moral depreciation

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

When evaluating the particular indicator of moral depreciation by normative or expert method, it is assigned a certain gradation (point). The best value of the moral depreciation indicator - very low - 1 point corresponds to an "excellent" grade, i.e. depreciation degree of 0 to 20%, which corresponds to the numerical grade of (0-0,2) on a Harrington scale. The worst value of the moral depreciation indicator - very high - 5 points corresponds to a "very bad" grade, i.e. depreciation degree of 80 to 100%, which corresponds to a numerical grade of (0,8-1,0) on the given scale.

Considering that the significance of each particular indicator of moral depreciation for the general indicator is different as a rule - it is necessary to determine the "weight" of a concrete particular indicator. The "weight" of each concrete particular indicator as a significance of the general indicator, should also be evaluated by a group of qualified experts in accordance with standard methods [12].

It is advisable to interprete the general indicator of moral depreciation of a concrete specific object geometrically in the form of a circular chart with a radius equal to a unit containing separate sections corresponding to the particular ones. It contains separate sections corresponding to particular indicators of moral depreciation of the given general indicator - as shown in Figure 3. In this case, the maximum value of the general indicator of moral depreciation which equals 1 or 100% can be expressed in terms of a unit circle area multiplied by a coefficient $1/\pi$.

The actual value of the general indicator of moral depreciation equals a sum of the sector areas multiplied by a coefficient $1/\pi$, with radiuses corresponding to the gradation of each particular indicator and an opening angle proportional to the "weight" of the particular indicator.

Figure 4 shows an example of determining the general indicator of moral depreciation by using Harrington scale and circular unit chart.

Let the general indicator $P_4$ be characterized by 4 particular indicators: $P_{41}=4$, $P_{42}=5$, $P_{43}=3$, $P_{44}=4$, at that the "weight" of indicators - opening angles of the sectors will be: $\beta_{41} = 0{,}25$; $\beta_{42} = 0{,}25$; $\beta_{43} = 0{,}375$; $\beta_{44} = 0{,}125$.

Then, to determine the general indicator of moral depreciation P4 we define the area of the figure $S_{ABCDEKN}$, as the sum of the areas of relevant sectors, multiplied by a coefficient $1/\pi$.

$$S_{ABCDEKN} = (S_{AOB} + S_{COD} + S_{EOK} + S_{NOA}) \cdot 1/\pi$$
$$S_{AOB} = \pi \cdot r^2 \cdot 0{,}25 = \pi \cdot 0{,}8^2 \cdot 0{,}25 = 0{,}16 \cdot \pi ;$$
$$S_{COD} = \pi \cdot r^2 \cdot 0{,}25 = \pi \cdot 1^2 \cdot 0{,}25 = 0{,}25 \cdot \pi ;$$
$$S_{EOK} = \pi \cdot r^2 \cdot 0{,}375 = \pi \cdot 0{,}63^2 \cdot 0{,}375 = 0{,}15 \cdot \pi ;$$
$$S_{NOA} = \pi \cdot r^2 \cdot 0{,}125 = \pi \cdot 0{,}8^2 \cdot 0{,}125 = 0{,}08 \cdot \pi .$$
$$S_{ABCDEKN} = 0{,}64$$

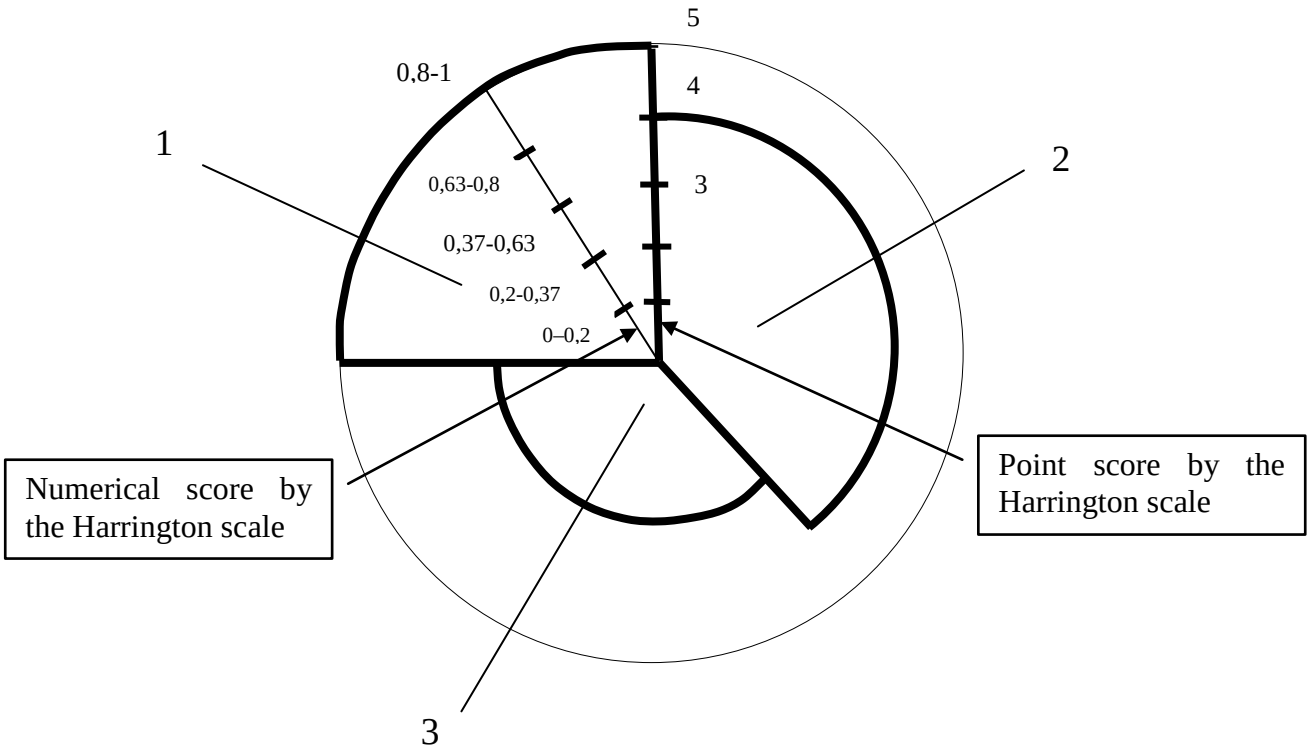
The general indicator of moral depreciation - $P_4 = 0.64$ or 64%, that according to the verbal score by the Harrington scale corresponds to the "high" score, and equals 4 points by the point score.

Similarly, we define the integral indicator of moral depreciation of each specific object as a set of general indicators of moral depreciation which have already been measured by the Harrington scale at the previous stage (see an example in Figure 4) with the "weights" of importance assigned by a group of qualified experts.

Let the order of actions described above be called the method of "folding" the particular indicators of moral depreciation into the general one. Under this method the "folding" of general indicators into integral indicators of moral depreciation of specific objects; integral indicators of the general object etc. is performed in order to receive the value of the integral indicator of moral depreciation of the CPF as a whole by the upward movement upon the levels of the CPF moral depreciation indicator tree.

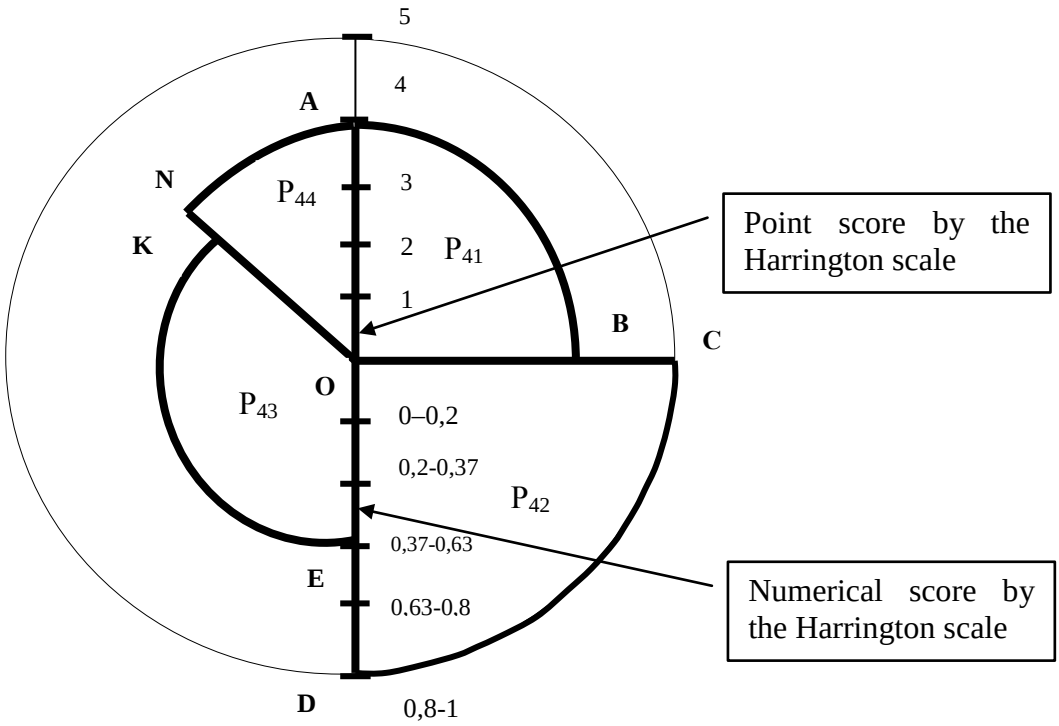
In accordance with the object structure (Figure 1), with the use of the theory of multilevel hierarchical systems [9], the integral indicators of physical depreciation of the whole CPF are represented as a set of integral indicators of physical depreciation of its components. Similarly, the integral indicators of physical depreciation of the components are represented as a set of integral indicators of physical depreciation of its general components or objects, and integral indicators of physical depreciation of general objects are represented as a set of integral indicators of physical depreciation of its specific components or objects. Based on the above, the physical depreciation indicator tree is shown in Figure 5.

Analysis of the techniques and methods for determining the values of the indicators of physical depreciation suggests that the indicators of physical depreciation of specific objects are defined in a number of cases by the normative method, such as for example physical depreciation of buildings.



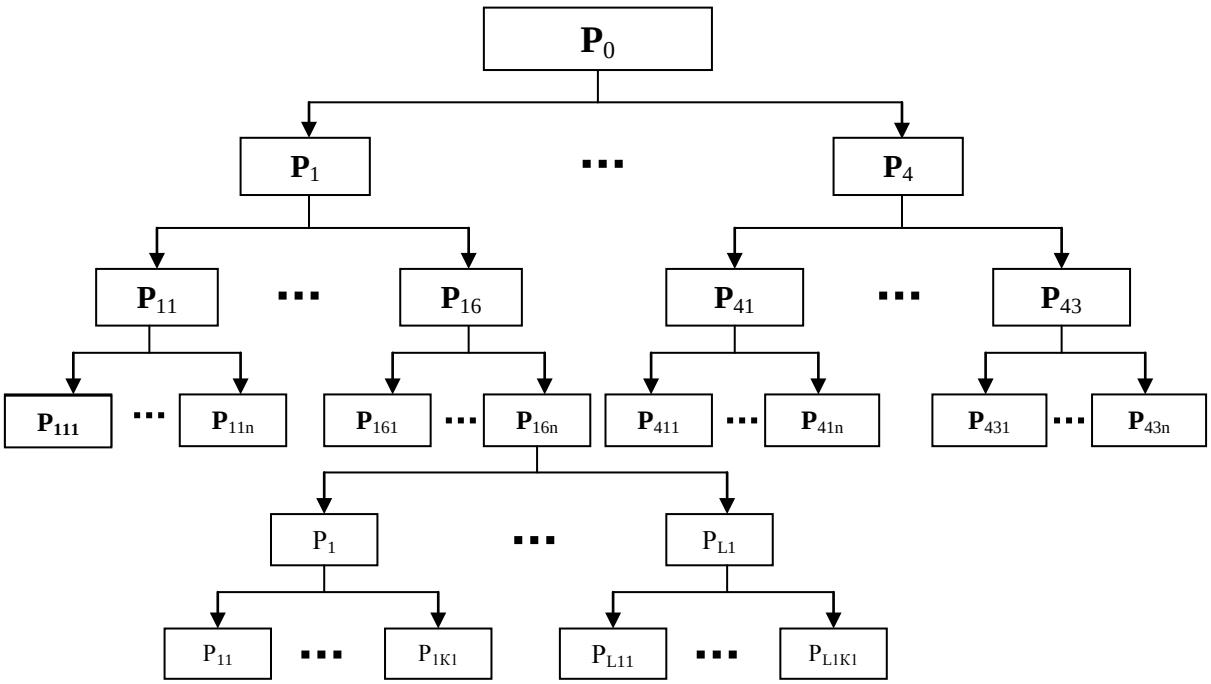

1, 2, 3 – sectors corresponding to the particular indicators of moral depreciation, with the radius equal to the point score by the Harrington scale and opening angle proportional to the "weight" of the particular indicator.

Fig. 3. The CPF moral depreciation indicator tree.




$P_{41}$, $P_{42}$, $P_{43}$, $P_{44}$ – particular indicators of moral depreciation.

Fig. 4. An example of applying the unit circular chart with the Harrington scale for determining the general indicator of moral depreciation P4




P1,1 = $\overline{1,L1}$ - indicators of physical depreciation of constructions or elements of the specific objects

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

**P** – integral indicators of physical depreciation of the CPF, its components, general and specific objects.

Figure 5. CPF physical depreciation indicator tree.

However, there are no normative methods to determine the integral indicators of physical depreciation of a number of specific objects (parks, public gardens, car parks, etc.), so it is advisable to determine these indicators by expert method [12]. Thus, the general technique of determining the indicators of physical depreciation of the CPF and its components should consist of the following two specific techniques for determining the values of the integral indicators of physical depreciation:

1. The technique of determining the values of integral indicators of physical depreciation of specific objects on the basis of the normative method or expert method [12].

2. The technique of determining the values of integral indicators of physical depreciation of general objects, components of the CPF and the CPF itself, based on the expert method of determining their importance - "weight" and on the method of "folding" the values of the indicators of physical depreciation of specific objects into the values of physical depreciation of general objects etc. by combining the circular chart with the Harrington scale. A more detailed description of such a combination is shown at the "folding" of the indicators of moral depreciation.

As a result of applying the mentioned techniques, concrete indicator values of physical and moral depreciation of the CPF are obtained.

Further, to establish a rational form of CPF, in accordance with the "Problem Formulation" it is necessary to develop the technique for generating variants of the CPF.

The technique of the CPF variant generation consists of the following particular steps:

1. Defining the signs distinguishing the CPF within the whole urban development area.

2. Dividing CPF into parts within the rest of the urban development area on the basis of the established signs with the definition of their physical depreciation, and moral depreciation and technical comfort.

To fulfil the first step, we could choose the following territorial features.

1. The generating element of the assumed CPF, i.e. its main component, is the general object, i.e. residential buildings (RB), which is a part of an architectural-and-construction component due to Fig. 1. The choice of the general object RB as the generating element is caused by the fact that it takes the primary major vital needs of the society in decent housing into account.

2. Existence of the other three CPF components, namely: engineering networks, engineering transportation, territories and spaces, in accordance with Fig. 1.
3. Natural borders existing in urban development areas: streets, roads, rivers, forest belts, etc.

Thus, at a stage of generation of variants proceeding from the given territorial features, the following structural elements of urban development could be referred to CPF: residential area, residential community and housing estate due to Fig. 6.

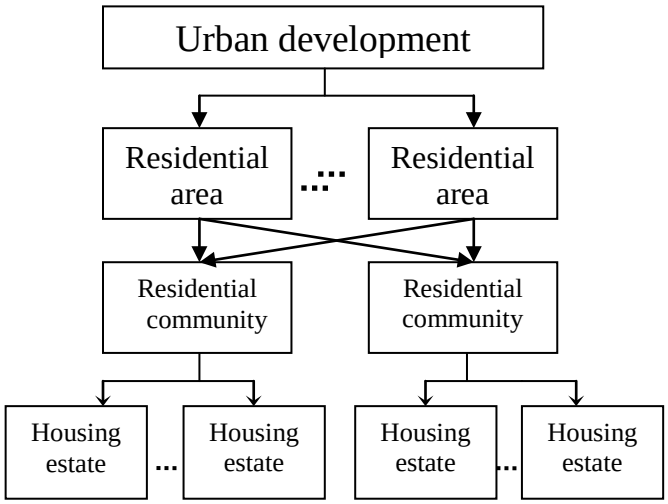



Fig. 6. Possible territorial distinguishing of CPF as structural elements of the urban development.

According to the above listed territorial features, residential areas and communities in the urban development areas are structurally isolated and administratively established. In accordance with the previously developed technique, P, M indices should be calculated for them.

Next, the residential areas or communities with high indices of P and M, are considered for planning of renovation and reconstruction.

Then it is necessary to develop a technique of rational distinguishing of the CPF in the form of housing estates within a certain area or community. Housing estate is a group of residential buildings and service establishments formed as a complete architectural and construction complex.

The general order of actions while implementing the second step for the formation of a variety of possible CPF variants on the territory of the residential area or community consists in the following:
1. Preparation of the basic data by creation of the cadastre of a compact built-up housing development area of the specific residential district or community in the form of its electronic digital card containing the general planning of the area. The card should contain a layer-by-layer detailed image of residential groups of buildings and blocks, daily service establishments for the inhabitants, engineering networks and communication, streets, roads and passages, green areas, reservoirs, parking lots, etc., as it is shown in Fig.7.

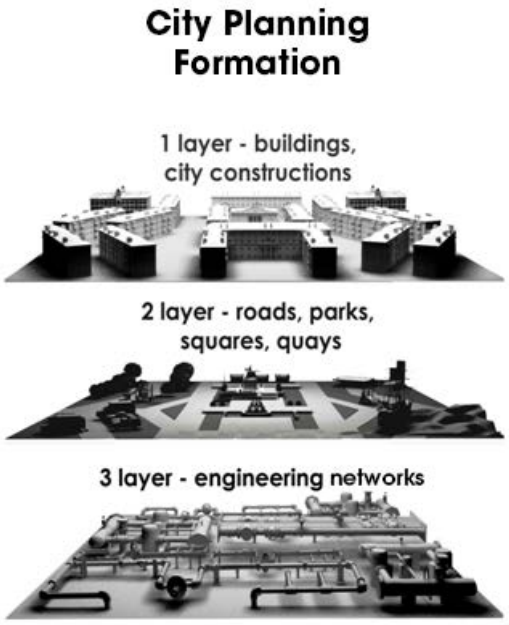



Fig. 7 – Layer-by-layer image scheme of the CPF components and objects.

2. Distinguishing CPF within the urban development area includes:
- selection of generating elements on the electronic card – residential buildings or their sets as a part of an architectural and construction component provided that they are surrounded by the other three CPF components in accordance with Figure 1;
- contouring of generating elements or their sets together with three components of CPF by the natural boundaries: roads, forest belts, etc., resulting In a certain *m*-th variant of partition consisting of a set of CPF with numbers $n = \overline{1, N1}_m$ ;
- formation of the complete list of features of the each CPF structure (specific and general objects and components) for the each variant of partition, with definition and recording of P, M indices of the specific objects.

The evaluation technique of the chosen variants' efficiency presupposes definition of the list of efficiency indices of partition of a residential area or community into CPF.

During formation of variants of dividing a residential area or community into CPF it is reasonable to seek the minimal dispersion of P and M, as well as number of storeys (S) of the groups of residential buildings included into a certain CPF. The proximity of index values of P and M and number of storeys S of the residential buildings which are a part of CPF, caused by similar condition of depreciation of the considered objects and a certain similarity of a space-planning view will promote the type-design practice of constructive as well as organizational- and- technological decisions made during designing the reconstruction and renovation of this CPF, as well as the introduction of the line production method of work that will allow to reduce the timing and cost of reconstruction.

Since there are quite a lot of variants of dividing a residential area or community into CPF and the process of partition is considered to be heuristic, then the values of M and P are assumed to be random variables. Therefore, as efficiency indices of the chosen variants of partition it is reasonable to deside on the weighted average dispersion of the values of M, P and S, which characterizes dispersion and scattering of these values over the groups of residential buildings inside the considered *n* variant of CPF for the *m*-th variant of division.

Formally it could be presented in the way shown in Fig. 8.

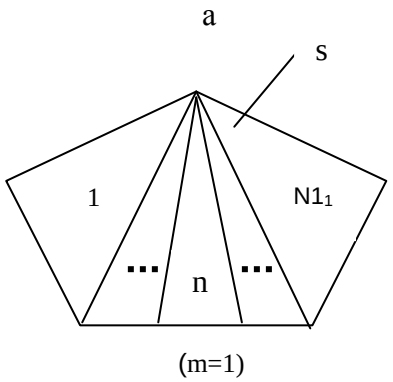
Dispersions on P, M, S of the residential buildings within the n variant of CPF at the m variant of partition can be represented as follows:

$$DP_n^m = \frac{I}{I1_{nm} - 1} \sum_{i=1}^{I1_{nm}} \left( X_{0P} - X_{iP} \right)^2, \quad (1)$$

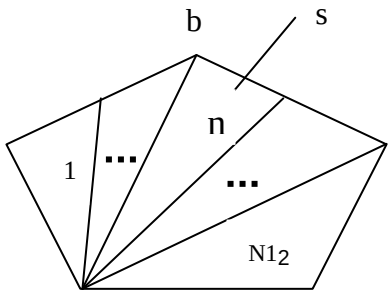
$$DM_n^m = \frac{I}{I1_{nm} - 1} \sum_{i=1}^{I1_{nm}} \left( X_{0M} - X_{iM} \right)^2, \quad (2)$$

$$DS_n^m = \frac{I}{I1_{nm} - 1} \sum_{i=1}^{I1_{nm}} \left( X_{0S} - X_{iS} \right)^2 \quad (3)$$

where, $DP_n^m$, $DM_n^m$, $DS_n^m$ are, respectively dispersion of physical depreciation, of moral depreciation and of the number of storeys of residential buildings within the *n*-th variant of CPF at the *m*-th partition variant; $I1_{nm}$ is the total number of residential buildings within the *n*-th variant of CPF at the *m*-th partition variant; $X_{0P}$, $X_{0M}$, $X_{0S}$ – are, respectively, an average physical depreciation, an average moral depreciation, an average number of storeys index for all residential buildings within the *n*-th variant of CPF at the *m*-th partition variant; $X_{iP}$, $X_{iM}$, $X_{iS}$ are, respectively, an average physical depreciation, an average moral depreciation, an average number of storeys index for all residential buildings within the *n*-th variant of CPF at the *m*-th partition variant.




(m=1)




(m=2)

S is the territory of a residential area or community partitioned into CPF – housing estates;
a and b are the schemes of variants of partition of the territory of a residential area or community into CPF - housing estates; and $n = \overline{1, N1}_m$ are numbers of CPF variants in different schemes of partition.

Fig. 8. Schemes of possible partition of the territory of a residential area or community into CPF

The efficiendy indices of the *m*-th variant of dividing ($m = \overline{1, M1}$) a residential area or community into CPF are the average dispercions on physical depreciation $DP^m$, moral depreciation – $DM^m$ and number of storeys – $DS^m$ of residential buildings of the residential area or community, which are calculated in the following way:

$$DP^m = \frac{1}{N1_m} \sum_{n=1}^{N1_m} DP_n^m \quad (4)$$

$$DM^m = \frac{1}{N1_m} \sum_{n=1}^{N1_m} DM_n^m \quad (5)$$

$$DS^m = \frac{1}{N1_m} \sum_{n=1}^{N1_m} DS_n^m \quad (6)$$

Thus the choice of the rational variant of dividing a residential area or community into CPF could be made at the minimal average dispersion of P parameter with the restrictions on the average dispersions of *M* and *S* parameters. Then the criteria of the choice of variant of partition of the territory of a residential area or community into CPF will be represented as follows:

$$\min DP^m = \min \frac{1}{N1_m} \sum_{n=1}^{N1_m} DP_n^m \quad (7)$$

$$< m=\overline{1, M1}>$$

under the restrictions of

$$DS^m = \frac{1}{N1_m} \sum_{n=1}^{N1_m} DS_n^m \le DS_0 \quad (8)$$

$$DM^m = \frac{1}{N1_m} \sum_{n=1}^{N1_m} DM_n^m \le DM_0 \quad (9)$$

where $DS_0$ is the limiting dispersion on the number of storeys, given on the basis of the number of storeys of residential buildings on the territory of the considered residential area or community; and $DM_0$ is the limiting dispersion on the moral depreciation, given on the basis of the moral depreciation of the residential buildings on the territory of the considered residential area or community.

Such an approach is confirmed by a successful method of reorganization of a part of the housing estate carried out in the housing area of Gardsten, Sweden [14]. In this housing area three-storeyed buildings were selected with similar constructive and space-planning indices, having nearly equal P and M values. Thus, due to standard constructive and technological as well as architectural solutions on P and M elimination, and also due to the introduction of line production methods of working, the modernization of the housing estate was completed with high quality and undertime.

The choice of a variant of dividing the territory of a residential area or community into CPF, which establishes the borders and form of this CPF, could be also influenced be other subjective factors which are the accessory factors at the decision making, as they significantly depend on a concrete location of the considered residential area or community, its content, financial and economic potential, and population structure. Among such factors are the following: readiness to carry out the financing of the reorganization of a concrete CBDA by certain structures (by industrial enterprises, since workers and employees of a certain concrete enterprise live since in this area, or by commercial organizations, since they could receive considerable benefits from granting favourable terms for renting offices and territories for small and medium business expansion, as examples); the importance of the concrete area from the position of the objects located there which have historical and architectural value; the importance of the concrete area as a developed center of the city or housing district, forming its functional and composite purpose.

# 4 Conclusion

1. The methodological approach is developed for selecting the variants of the form of urban areas intended for reconstruction, providing the possibility of work execution with rational consumption of resources.
2. The list of efficiency indicators of rational variants of dividing a residential area or community into CPF – physical depreciation, moral depreciation and number of storeys of the residential buildings related to CPF.
3. The hierarchy of the indicators of moral and physical depreciation of CPF and its components is defined in the form of a "tree" which is relevant to the object structure of CPF.
4. The general technique is developed for determining the indicators of moral and physical depreciation of CPF and its components, consisting of two individual techniques. It includes both the normative method with instrumental measurement of quantitative indicators of depreciation, and the expert method in the absence of the relevant standards.
5. The technique of "folding" of the system of indicators of moral and physical depreciation of the underlying level, based on a combination of a unit circular chart with the Harrington scale.
6. The choice of concrete variants of dividing territories of a residential area or community into CPF, i.e. the form and structure of CPF with the purpose of its further renovation and reconstruction, should be carried out with consideration for the specified criteria, as well as, in a number of cases, with due account for the above mentioned subjective factors with involvement of experts, administrative authorities, interested social organizations and representatives of the population of these areas.

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