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FORMATION OF METHODOLOGICAL LEVELS OF ASSESSING CITY PUBLIC PASSENGER TRANSPORT EFFICIENCY

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Виділені методологічні рівні дослідження міського громадського пасажирського транспорту, проведений аналіз міжрівневих зв'язків, сформовані принципи системної оцінки ефективності його функціонування. Представлена формалізація складових елементів оцінки системної ефективності міського громадського пасажирського транспорту шляхом синтезу міжрівневих оціночних параметрів ефективності та квантифікації переваг станів елементів з урахуванням умов обліку функції прирощення ефективності метасистеми

Ключові слова: міський громадський пасажирський транспорт, метасистема, системна ефективність, методологічний рівень дослідження

Выделены методологические уровни исследования городского общественного пассажирского транспорта, проведён анализ межуровневых связей, сформированы принципы системной оценки эффективности его функционирования. Представлена формализация составляющих элементов оценки системной эффективности городского общественного пассажирского транспорта путем синтеза межуровневых оценочных параметров эффективности и квантификации преимуществ состояний элементов с учетом условий учета функции приращения эффективности метасистемы

Ключевые слова: городской общественный пассажирский транспорт, метасистема, системная эффективность, методологический уровень исследования

1. Introduction

The problem of improving the quality and efficiency of the city public passenger transport (CPPT) functioning is relevant for all cities without exception. The reason for the significant attention to the issue of improving the CPPT functioning is its high level of influence on the social, economic and ecological constituents of modern city life. The CPPT along with the individual passenger transport takes a special place in maintaining the life of the urban environment, influences the quality of living in it to a great extent and determines the conditions of the local budget formation [1–3]. The assessment of the CPPT efficiency is one of the key tasks of forming the concept of the city passenger transport improvement and requires the creation of the methodology of objective representation of the transport process results from the multilevel evaluative positions [4].

The development of functional plans for improving the city passenger transport takes an important part in building up the strategy of the constituent urban environment development. Maintaining a high level of the efficiency of the processes of CPPT functioning requires determining the rational conditions of its work and demands carrying out constant monitoring of its performance by assessing the results of its functioning. This procedure is implemented through the perspective assessment of the effectiveness of its functioning using the tools of the applied simulation apparatus and necessarily requires the calculation of the criterion of its functioning efficiency.

The structure and the composition of the efficiency criterion largely determine the strategy system of the CPPT presentation and the methodological levels of its research. The necessary condition of carrying out the efficiency assessment is the adaptation and the formal realization of the principles of the systematic approach aimed at the formation of a complex estimation of the CPPT influence on the vital spheres of the urban environment. Applying this approach allows increasing the level of the objectivity and the adequacy of the projective and the technological solutions which are implemented in the sphere of the city passenger transport.

2. Analysis of scientific literature and the problem statement

Defining the concept of the transport process efficiency, which can be represented as a category that describes the impact and the effectiveness of the functional processes is a baseline in the formalization of the indicators of the CPPT functioning. The transport efficiency reflects not only an increase in the transportation volume, but also provides an opportunity to determine by what price and by what volume of the resources this increase is achieved. The process of the passenger transportation in the city traffic has a wide range of effects on the urban environment that can be characterized by a large number of indicators, with a total number of more than fifty, among which one can distinguish the groups of the economic, technological, social and ecological parameters.

The availability of a wide range of factors of assessing the consequences of the CPPT functioning combined with the possibility of their structural variability led to the emergence of a significant number of research and scientific and practical approaches to assessing the CPPT functioning efficiency. The analysis of the works dedicated to studying the problems of increasing the CPPT functioning efficiency [5–13], allowed highlighting the strategic directions, which are essentially similar in the presentation of indicators, by which the effectiveness of the city passenger transport may be assessed. The following approaches can be referred to the following directions:

– formation of the CPPT efficiency on the basis of presenting the CPPT efficiency as a set of separate indicators of the transport service quality;

– creation of integrated efficiency indicator, which is formed by the synthesis of the qualitative characteristics of the transport process and technological parameters of the CPPT operation;

– development of the integrated indicators, in which the interests of the direct or indirect participants of the transport process are additionally taken into account.

The presentation of the CPPT functioning efficiency in the form of a single evaluation indicator gained a significant spread in the period of the CPPT technological development, which can be referred to the second half of the twentieth century. The possibility to use the passenger transportation time as an efficiency indicator is substantiated in the works [7–10]. The use of this approach to assessing the effectiveness of MGPT is explained by the fact that the time of the transportation is an effective parameter, on the basis of which one may make a general assessment of the CPPT efficiency. A variant of the presentation of a single CPPT efficiency indicator is the effectiveness assessment on the basis of the calculation of the total costs of the CPPT functioning that are defined as the costs value of the time for the passenger transportation and the costs of the transport enterprises for the CPPT route network servicing [11]. The presentation of the effectiveness of complex systems in the form of a single parameter conflicts with the system principle which is advisable to use only in terms of the individual system elements and has small prospects for the CPPT efficiency assessment from the positions of maintaining the transport consistency.

The implementation the CPPT efficiency assessment based on the formation of a set of indicators of the transport service quality, unlike a single indicator, expands the system of its presentation and allows increasing its formalization of the objectivity. This form of the CPPT efficiency assessment became widely spread in practice due to its simplicity of the presentation and the availability of the assessment information. Among the works that use this approach, it is possible to highlight the works dedicated to the formation of the indicators of the general CPPT efficiency assessment [10, 11]. The formation of a range of the efficiency indicators makes the procedure of assessing the CPPT efficiency difficult, since such a task becomes a multi-criteria one; it has a large number of forms of combining the system states and involves the subjectivity in determining the advantages of the individual indicators.

When evaluating the CPPT functioning efficiency, we use the approach, in which a complex principle of forming the CPPT efficiency assessment is implemented [12–14]. This approach involves the formation, with the help of different instruments, of a separate or an integral complex indicator of the CPPT functioning efficiency, which, as a rule, is implemented as the incorporation of the socio-economic results of its functioning and the synthetic indicators of the transport service level in one indicator, or a set of separate groups of indicators of the transport service quality. Using this approach allows expanding the range of the parameters of the CPPT efficiency assessment and increasing the objectivity level of its evaluation and provides a way of implementing the system approach principles. However, the existing methodologies involve the efficiency assessment only within the CPPT and do not include the effects of its influence on the environment in which it performs its functions. Such conditions make it possible to argue about the limitation of its use in the formation of the strategies of the consistent development of the urban environment and demand their development not only by expanding the range of the complex criterion constituents, but also by implementing the new mechanisms of forming the result indicator sets beyond it.

The main disadvantage of existing methods of the CPPT efficiency assessment is their system restrictions relative to the assessment objects. They are aimed at assessing the effectiveness as for the relative CPPT internal parameters (the passengers, the route network, the transport enterprises, etc.) and does not take into account the changes that can occur in an external – in relation to the CPPT – environment (the transport network of the city, the city functional environment, the environmental and the social structure of the city, etc.). The extension of the CPPT efficiency assessment zones is a complicated, non-trivial task, which requires the creation of a new methodological apparatus of the CPPT system presentation and efficiency assessment. This allows substantiating the necessity of forming the new methodological principles of the CPPT functioning efficiency assessment based on the system approach by its research as an integrative element of the higher level system.

3. The purpose and objectives of the study

The aim of the research is formulation of the principles of the CPPT system efficiency assessment by identifying the methodological levels of its investigation and the formation of the inter-level integrative assessment of its efficiency.

To achieve the set aim, the following tasks were solved in this work:

– on the basis of defining the stages of the CPPT system analysis from the positions of the multilevel approach, the methodological levels of studying its system efficiency were determined;

– the formal constituent elements of the CPPT system efficiency assessment were formalize by the synthesis of the multilevel evaluation and the quantification of the advantages of the elements states based on accounting the function of the increment in the metasystem efficiency.

4. Distinguishing the methodological levels of researching the system efficiency of the CPPT functioning

The aim of researching the CPPT efficiency is to form the strategy of its transition to a qualitatively new level which provides the opportunity for its sustainable development. Achieving this aim requires the use of the multilevel analysis in the study of its functioning, which by its structural sequence is implemented in accordance with the phases of studying the complex systems. The system research of the CPPT functional efficiency from the position of the multilevel approach involves defining and implementing the main phases of structural analysis of its complex system properties.

The quality of the complex system is revealed in full only in the course of its operation, i.e., in targeted application. Therefore, the most objective assessment of the CPPT system efficiency can be achieved by evaluating the level of its targeted application. The system efficiency is the ability of a system to achieve the goal in the set conditions of using resources and with the proper quality. Efficiency, as a property, is characteristic only for systems (organizational, technical, biological, etc.). The efficiency of a system can not be defined only by the properties of the system elements; it is also necessary to take into account the properties of the suprasystem to which it belongs. The efficiency of a particular system is determined through the system of the effectiveness criteria that characterize all the hierarchy levels of the system taking into account the external ones.

In the system description of the CPPT, it is important to find a compromise between the simplicity of its description and the necessity of taking into account the behavioral features of the elements. The solution to this dilemma is to use the hierarchical approach. The hierarchical approach to presenting CPPT is realized by the formation of a family of models, each of which describes its behavior in terms of the different abstraction levels. For each level, there are a number of characteristic features and variables, laws and principles, by means of which the PCCT behavior is described. For this description to be effective, the objective formalization of the inter-system structural relations in ensuring the maximum possible independence of the models for the different system levels is necessary. The implementation of the systematic approach to determining the PCCT efficiency requires the determination of the system structure and limits, the formalization of the relations between its elements, the definition of the certain target priorities of functioning, the distribution of the internal processes and subsystems, the assessment of the resource capacity level and defining the influence of the result of functioning of the high level. While investigating the complex systems as a system of the higher level, the concept of the metasystem is used [15]. The metasystem is a relatively new concept, by which we imply a large-scale system, wider than the traditional systems, in which every investigated system is a constituent part with the rights of a separate system.

The metasystem is different from the structured system by the following features:

– condition for the identifying the elements of the metasystem is the quantification of the goals of functioning on the basis of the analysis of the conditions of the subsystem completeness and sufficiency;

– relations between the elements of the metasystem, unlike those of the structured system, are formed on the basis of the resource-efficient intersystem streams, which is the result of the availability of a high self–sufficiency level of its constituent elements;

– achievement of the global goal of the metasystem operation is ensured by the aggregate results of the subsystems operation and implemented on the basis of the integration of functioning of the individual subsystems or a complex of them.

The CPPT is a constituent element of the social environment and aims at meeting the needs of all kinds of transportation and all forms of streams. The CPPT can be presented as a constituent system of the metasystem "the city environment" (CE). The experience in the studying complex systems allows presenting the CPPT from the positions of its being a part of the metasystem CE and involves identifying four methodological levels of the system investigation of its effectiveness (Fig. 1).

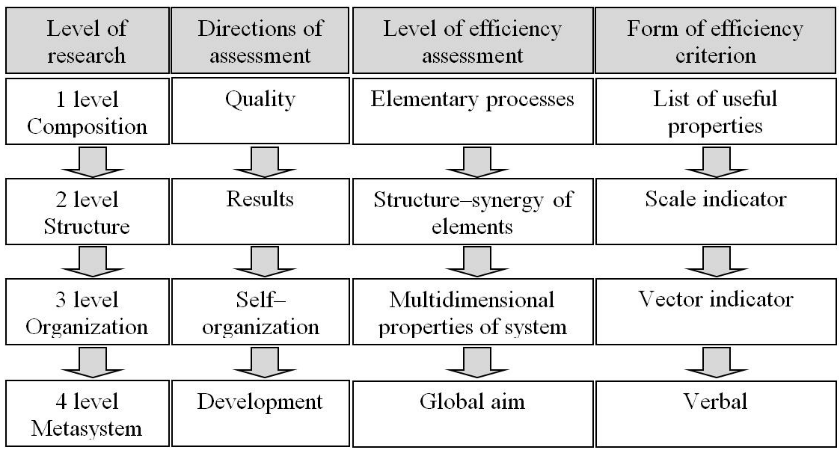

Fig. 1. Methodological levels of researching the CPPT system efficiency

The important stage of presenting the methodological levels of the research into the CPPT functioning is the formalization of the efficiency evaluation forms. Starting from the third level of researching, the CPPT is necessary to be considered not as a separate system, but as a constituent metasystem element. The consideration of the effectiveness from the positions of a metasystem is impossible to carry out without the consideration of the system usefulness; it has a correlation link with the structure and properties of all levels of the system hierarchy. The assessment hierarchy of the CPPT system efficiency is a sequence of the transformation of its form: from the enumeration of it properties to its verbal description that reflects the influence of the constituent higher level elements of a metasystem.

The overview of the works [7–14], devoted to studying the CPPT functioning, showed that its majority examines it at the structure level which is presented by a route system, only in the separate works, the research in the CPPT as an organization corresponding to the third level is suggested. However, the modern conditions of the city life require moving the focus to the sphere of the metasystem while determining the efficiency of the transport system functioning. The reason for this is the shortage of the recourse capacities and constantly growing negative impact of the CPPT on the living conditions of the population. The problem of increasing the efficiency of the CPPT functioning is a strategic task of not only the individual subjects of the transport complex, but also the problem of the city socio-economic area, besides, it largely determines the priorities of improving the population quality of life.

The way the task is set requires solving the problem of assessing the functioning of not the separate systems of maintaining the vital aspects of the urban environment, but forming the conditions for realizing the potential of the whole urban environment and assessing its development. Taking this into account, there is the urgent need for the implementation of the methodological level of researching into the CPPT system efficiency from the positions of a metasystem to which it belongs. At this level, it is necessary to investigate the global goal of the metasystem functioning and to determine the level of the CPPT influence on achieving it. The complexity of this level representation lies in the impossibility of its clear formalization. The metasystem analysis is possible only at the verbal level. The efficiency of the metasystem functioning is formed on the basis of logic and can be formalized with the help of Boolean algebra.

5. Formation of the CPPT system efficiency assessment of the basis of the quantification of the advantages of the metasystem levels states

When evaluating the effectiveness of the complex systems functioning, retrospective and perspective approaches are used. Depending on the set goal of the efficiency assessing, the parameters of the system in the form of the statistical data obtained as the results of observing the system functioning or the mathematic expectations of the system operation results (possible result) are analyzed. The system functioning result reflects its quality status and is determined by its methodological review level and can be represented as a vector of the achievement of the chosen aim according to the effectiveness criterion level.

The process of the CPPT functioning is considered as converting resources into the result which aims to meet the multi-level needs of the urban environment population. By the CPPT functioning, the set of the sequential changes of the input and output parameters of its elements should be understood. The input parameters are a set of resources that are used; the output parameters are the result. The important role in providing the conditions for the efficient CPPT functioning is played by the factors of influence that have a different nature of influence and of the basis of formation. Having formalized the CPPT constituents through the set of the resource-effective components of each methodological level of the research, it becomes possible to present the system state in the form of the matrix:

$$S_s = \begin{bmatrix} A_m & R_m & G_m \\ A_t & R_t & G_t \\ A_u & R_u & G_u \\ A_g & R_g & G_g \end{bmatrix}, \tag{1}$$

where A_m, A_t, A_u, A_g are the result of functioning of the system of a correspondent level: composition, structure, organization, metasystem; R_m, R_t, R_u, R_g are the resources of the appropriate level: composition, structure, organization, metasystem; G_m, G_t, G_u, G_g are the factors of the influence on the correspondent level: composition, structure, organization, metasystem respectively.

The efficiency assessment for a specific level of its analysis is viewed as a certain function or a functional which reflects the synthesized indicator of the obtained results, the volume of the used resources and the factors of influence:

$$E_k = \Phi(A_k, R_k, G_k), \tag{2}$$

where E_k is the performance indicator of k-level; A_k is the possible or actually achieved final result of the system functioning at level k; R_k is the possible or actual resource costs for obtaining the result S_k on the k-level; G_k is the possible or actual impact of the factors on the system functioning for obtaining the result S_k on k-level.

System efficiency of the CPPT can be presented in the form of the matrix-column which displays the level of efficiency of all levels:

$$E_S = \begin{bmatrix} E_m \\ E_t \\ E_u \\ E_g \end{bmatrix}, \tag{3}$$

where E_m, E_t, E_u, E_g is the indicator of functioning efficiency of the system of a correspondent level: composition, structure, organization, metasystem.

The system inter-level integration of the efficiency assessment is implemented by the synthesis of all levels of the efficiency assessment and formalized in the form of the union of sets:

$$E_m \subset E_t \subset E_u \subset E_g, \tag{4}$$

where E_m, E_t, E_u, E_g are the set of the parameters of the system efficiency assessment of a correspondent level: composition, structure, organization, metasystem.

An important factor that influences the CPPT effectiveness is its complexity, which is characterized by the presence of the appropriate number of elements and the appropriate number of the states of the system. The system description of the CPPT functional efficiency from the positions of a metasystem involves the description of the elements in the form of the final set and the character of the interrelations between them. A special attention in the formation of the complex systems efficiency should be paid to their balance, which is achieved by accounting the internal conflicts and compromises [16]. The realization of such compromises is achieved by implementing the principles of the system balance. This approach involves the description of the interaction between the system elements in the general form, taking into account all the factors of the conflict formation and the possible character of their interaction, causes and mechanisms of conflicts.

In the formation of the CPPT system effectiveness, it is necessary to consider the possible conflicts of the different levels. To do this, it is necessary to build a model of forming of the inter-level advantages as a tool of the quantification of the purposes of complex systems. For the formalization of such a model, we will define the concept of the “metalevel” The aim of the level is formed on the basis of the quality purpose of the system elements of the corresponding level. The condition for achieving the effective metasystem state is the coordination of the components results with the general purpose. Thus, the efficiency of the first level should correspond to the achievement of the purpose of the first level, the efficiency of the second level should correspond to the purpose of the second level, etc. The definition of the purposes of different levels is formed on the basis of building up a purpose tree. The definition of the system state of each level ensures approaching a metasystem ultimate goal or distancing from it. When comparing the system states of the same level, it is possible to establish four types of relations [16]:

$$S_k^i \overset{M_{k+1}}{\succ} S_k^j,\ S_k^i \overset{M_{k+1}}{\succ} S_k^j,\ S_k^i \overset{M_{k+1}}{\cong} S_k^j,\ S_k^i \overset{M_{k+1}}{\neq} S_k^j, \qquad (5)$$

where S_k^i is the state of i – variant of the system of k-level; S_k^j is the state of j – variant of the system of k-level; M_{k+1} is the purpose of functioning of the system of the level following k-level; $\overset{M_{k+1}}{\succ}$ is the level of the advantage of i – variant of the system over j – variant as for the purpose of functioning of the system of k+1-level; $\overset{M_{k+1}}{\prec}$ is the level of disadvantage of i – variant of the system over j – variant in relation to achieving the purpose of functioning of the system of k+1-level; $\overset{M_{k+1}}{\cong}$ is level of the equivalency of i – variant of the system to j – variant in relation to achieving the purpose of functioning of the system of k+1-level; $\overset{M_{k+1}}{\neq}$ is the level of the impossibility of comparing the advantages of i – variant of the system over j – variant in relation to achieving the purpose of functioning of the system of k+1-level.

Based on the nature of the character of relations, it is possible to carry out the procedure of finding the rational state. The search for the effective state of the system is made from a set of available alternatives to the system state of each level by choosing the variant that matches the criteria ensuring the efficiency of the system of higher level:

$$S_k^i \overset{M_{k+1}}{\succ} S_k^j \Rightarrow E_{k+1}^i > E_{k+1}^j. \qquad (6)$$

The choice of the CPPT functioning option from the position of the metasystem can made by constructing a graph of congruence of the relationships between the system levels. However, this approach allows only defining the general directions of the subsystems development and does not allow using it to solve the specific problems of finding the rational conditions of the functional processes. To determine the rational states of the metasystem it is necessary to ensure the transition from the binary relations to determining the advantages by the efficiency criteria. The efficiency is determined by the parameters that have separate measuring scale in accordance with each level. The change in the system efficiency at a certain level is achieved not only through the operating measures at this level, but is implemented through the measures implemented at the lowest level. The change in the system efficiency of functioning is determined through the assessment of a possible state of the system of a higher level:

$$\Delta E_k^i = E_{k+1}^i(A_{k+1}^i, R_{k+1}^i, G_{k+1}^i) - E_{k+1}^j(A_{k+1}^j, R_{k+1}^j, G_{k+1}^j), \qquad (7)$$

where ΔE_k^i is the function of the increment in the functioning efficiency of the system of k-level which is achieved through the implementation of the i-level of the CPPT.

Getting a negative increment in the efficiency at level k+1 needs an additional amount of resources of level k+1 as a compensation. The achievement of the result level is realized through the inter-level increment in the result:

$$A_{k+1}^i = (A_{k+1}^j + \Delta A_{k+1}^j), \qquad (8)$$

where ΔA_{k+1}^j is the inter-level increment in the result of the CPPT functioning at the level k+1.

The implementation of these conditions is possible through the use of the positive CPPT resources of the appropriate level:

$$A_{k+1}^j + \Delta A_{k+1}^j \Rightarrow R_{k+1}^j + \Delta R_{k+1}^j. \qquad (9)$$

The increment in resources for achieving the result leads to a decrease in the effectiveness

$$E_{k+1}^i(A_{k+1}^i, R_{k+1}^i, G_{k+1}^i) > \\ > E_{k+1}^j(A_{k+1}^j + \Delta A_{k+1}^j, R_{k+1}^j + \Delta R_{k+1}^j, G_{k+1}^j + \Delta G_{k+1}^j). \qquad (10)$$

When evaluating the effectiveness of the CPPT functioning from the positions of the sustainable development, it is worthwhile using the coefficient of the resource capacities as an indicator of the assessment of the system sustainability level [17]. When we set the task in this way, the dependence of the transition of the resource providing states takes the form:

$$A_{k+1}^j + \Delta A_{k+1}^j \Rightarrow RR_{k+1}^j - \Delta RR_{k+1}^j. \qquad (11)$$

The formation of the resource reserves has the aim of ensuring the conditions for the stable functioning within the defined resource capacities of the system. The coefficient of the resource capacities reflects the share of the resources reserves and acts as a limitation of the choice of the system states from a set of the feasible options. The degree of conformity of the obtained effect with the level of maintaining the resources reserve is determined by the applicability terms relative to the reserves capacities:

$$\Delta KE_k = \max\left\{KR_k - KR_k^D; 0\right\}, \qquad (12)$$

where KR_k^D is the coefficient of the reserve capacities of the system which corresponds to its applicability for k-level; KR_k is the coefficient of the resource capacities of the system state for the k-level.

The applicability criterion of the resource capacity level is determined on condition of corresponding to the minimum accepted level of the reserve of resources that are used at the appropriate level of the CPPT presentation:

$$KR_k^D = \min\left\{r_{kn} \in \mu \middle| \mu_n \to r_{kn}^D, n = \overline{1,b}\right\}, \qquad (13)$$

where r_{kn} is the CPPT resource used at k-level; μ_n is the range of admissible values of the CPPT resource capacities; r_{kn}^D is the admissible values of the CPPT resource capacities within the circle described by the radius of the admissible values; b is the number of the CPPT resources types used at the correspondent level.

The range of the permissible values of the resource capacities for each level is determined by the essential terms of the resource reserves that ensure the sustainability of the correspondent level of a system:

$$\mu_n \in \left\{RR_n^D \middle| RR_n^D \subset RR_n^p\right\}, \qquad (14)$$

where RR_n^D is the admissible level of the resource reserves; RR_n^p is the range of the resource reserves which ensure the sustainable state of the correspondent level of the system.

Taking into consideration the conditions for forming the sustainable state of the system, the indicator of CPPT system functioning efficiency can be presented in the form of the aggregate of the functioning efficiency of the level and an additional constituent that takes into account the impact level of the resource capacities of the system:

$$E_s^k = E_k + \sum_{i=1}^{n} \frac{R_{i+1} \Delta KE_{i+1}}{\Delta A_{i+1}}, \; n = \overline{1,(m \underline{\vee} k)}, \tag{15}$$

where E_s^k is the CPPT functioning efficiency from the positions of k-level; m is the total number of the levels of forming an increment in the CPPT system efficiency.

The combination of the estimating parameters of different methodological levels within the general indicator of the CPPT efficiency requires a unification of their criterion rating system and is possible through the use of the process-oriented rating scale.

6. Discussion the results of forming the levels of the system efficiency of the city public passenger transport

The efficiency assessment of the CPPT functioning is an important task that lies beyond its internal environment and refers to the complex problems of the urban environment. The suggested approach to the evaluation of the CPPT system efficiency corresponds to the principles of the necessary variety of research into complex problems and allows creating a system of the general management of the structural elements of the city transport system, which is oriented to the final result of the city environment functioning. The conditions of the formation of this approach is the implementation of the suggested principles of the CPPT presentation in the form of a hierarchical complex system aimed at achieving the global goal of the city environment functioning. The suggested methodological levels of researching into the CPPT allow implementing the principles of the inter-level integrated assessment of its effectiveness and involves considering the CPPT functional processes as an internal environment of the global metasystem, the constituent element of which it is.

The implementation of the efficiency assessment system of the CPPT functioning allows including two basic integration concepts to its composition:

– the concept of the feedback of dynamic interactions of the participants at the different methodological levels, which allows implementing a form of the generalized description of the system structures and relationships;

– the concept of the imitation, which makes it possible to describe the changes in the state of the metasystem as a result of the formation of the specific processes within the CPPT.

The study of the laws of the metasystem development reveals the new opportunities in understanding the problems of increasing the efficiency and the CPPT organization and functioning. The conditions of maintaining the efficient metasystem state is introducing the principles of saving resources which aims at ensuring the CPPT state balanced with the external environment, and in which its maximum potential is realized. The increase in the level of external influence on the CPPT requires the mobilization of its self-organization processes. The idea of self-organization of the CPPT received its development within the synergetic concept, the aim of which is the formation of the general methodology of the internal and external elements interaction on the basis of the sustainable development principles. The concept of the CPPT system efficiency from the positions of the general metasystem gives an opportunity to estimate the additional factors of the stability of the developed project in the long-term prospect.

The condition for achieving a sustainable state of the city environment is the quantification of the advantages of the alternative states of its elements on the basis of accounting the function of the increment of the effectiveness of the correspondent inter-level resource-efficient parameters. The suggested form of the implementation of the CPPT system efficiency assessment corresponds to the principles of the sustainable development and allows implementing in practice the concepts of the information and mathematical CPPT models designed to imitate its behavior in terms of the metasystem in a certain time scale.

The approbation of the developed methodological principles of the CPPT efficiency assessment was carried out on the experimental CPPT network model of the Saltovskiy residential area in the city of Kharkov. To this purpose, within the framework of complex research, the model of the transport system of the investigated object was created in the software complex Vissum. The transport network of the researched area consists of 32 transport hubs and 48 networks sections. 15 CPPT routes function in the framework of the transport network. The information about the traffic intensity in the network sections and the data about the passengers flow on the routes during the morning rush-hours were collected by means of the field observations. The level of adequacy of the developed model meets the criteria of the experimental research. The evaluation parameters of the efficiency assessment for every defined methodological level were formulated through the expert research and analytical calculation:

– the first level – indicators of the passenger transportation quality within the route network (accessibility, descriptiveness, timeliness, reliability, safety and comfort);

– the second level – an indicator that reflects the transport process effectiveness (conditional cost value of the transportation taking into account the needs satisfaction level);

– the third level – indicators of the efficiency of using the transport network (the level of convenience of the vehicle functioning);

– the fourth level – an indicator of the impact on the city environment (ecological and social quality grade).

The condition of the maintenance of the CPPT functioning is the use of the resources distributed within the first three levels. These resources include the technical resources (roadway, vehicles belonging to the transport enterprises), economic resources (passengers' money, costs of the transport enterprises, the local budget costs) and the resources of the city environment (land resources, ecological and social resources). The ratio of the received results to the volume of the used resources gives an opportunity to assess the effectiveness of a particular system element at the correspondent level. The difference between the volume of the available and used resources determines the volume of the reserves, which, in their turn, affect the efficiency of the whole system. The efficiency is represented in relative indicators and is determined on the basis of the calculation of the capacity coefficients [17].

Calculations with the use of the additional software module in the software medium Vissum allowed defining the efficiency parameters for the first (the routes), the second (the transport company) and the third level (the transport network) of the research. For the fourth level, the effectiveness is determined by the verbal description of the influence on it. As the measure to implement for changing the CPPT state, an alternative solution was suggested that involves increasing in the transport enterprises capacities (an increase in the vehicles on certain routes) and the reallocation of the available resources of the transport network between the individual and the public transport (redistribution of the traffic lanes). After the calculations, the indicators of CPPT functioning efficiency at each level were obtained. They are presented in Table 1.

Table 1

Efficiency of functioning of the CPPT of Saltivskiy residential area

Presentation level	Available variant	Alternative area	Deviation
1 level – quality (routes)	0,18	0,29	+0,11
2 level – effectiveness (transport enterprises)	0,12	0,03	–0,09
3 level – comfort (transport system)	0,38	0,32	–0,06
4 level – impact on the environment (city environment)	–	deterioration	deterioration

The obtained data indicate that with ensuring the increment in the efficiency at the first level, the deterioration of the effectiveness at the other three levels was observed. The character of such dependence is explained by the presence of the multi-level links: the increase in the number of vehicles on the routes leads to the increase in costs and in the cost value of the transportation; the redistribution of the traffic lanes for the priority motion of the CPPT vehicles leads to the increase in traffic along the other lanes and the emergence of traffic jams, and this consequently leads to the deterioration of the ecological situation. Accounting these relationships with the help of the dependence (15) allows drawing a conclusion about the negative overall effect from the positions of the metasystem at level – 0.04, which demonstrates the ineffectiveness of such measures. The presented calculations were performed without determining the weight coefficients for each efficiency assessment level.

The prospects of the further research in the field of assessing the CPPT system efficiency lie in performing the parametric analysis, which refers to one of the most difficult tasks and involves forming the distribution conditions and rules for the correspondent methodological levels in the organizational hierarchy of the necessary and sufficient aggregate of the indicators, which characterize the CPPT properties aimed at achieving the main aim of the metasystem.

7. Conclusions

1. The condition for the formalization of the CPPT system functional efficiency is the use of the systematic approach, which is implemented through defining four stages of structural analysis of its system properties. On the basis of the integration of the stages and forms of the analysis, four methodological levels of investigating the CPPT functioning were distinguished. The suggested methodological levels of the CPPT investigation determine the conditions of its system representation and allow implementing the concept of the formation of the conditions for the sustainable development of the city environment. The following hierarchical forms of the CPPT efficiency assessment – composition, structure, organization and metasystem – were defined and formalized as the methodological levels of the CPPT investigation. The suggested levels reflect the conditions of the formation of the hierarchy of the CPPT functioning aim in the conditions of the global environment of its functioning and allow defining the following directions of its efficiency assessment: quality, effectiveness, opportunity for the self-organization and development.

2. Accounting the system of conflicts under the conditions of the proposed levels of the CPPT representation was implemented on the basis of the proposed model of the formation of the inter-level advantages, which involves at each level carrying out the accounting changes in the efficiency indicators of the other levels. The quantification of the purposes of the CPPT states formation is carried out on the basis of the assessment of the function of the increment in the metasystem effectiveness, which is presented as an additional component of the efficiency criterion and takes into account the impact on other system levels of the resource effective opportunities of the elements of the corresponding metasystem levels. The suggested approach can serve as a basis for designing the functional strategies of the city transport system development and for creating the analytical models of the formation of the organizational and managerial aspects of the CPPT functioning.

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