DOI: https://doi.org/10.32347/2707-501x.2023.52(1).123-137

**УДК 693. 546**

**A.F. Osipov,**
Dr. Tech. sciences, professor
ORCID: 0000-0002-5463-3976
*Kiev National University of Construction and Architecture*

# INTRODUCTION TO THE THEORY OF SUSTAINABLE OPERATION OF TECHNOLOGICAL SYSTEMS FOR BUILDING RECONSTRUCTION

*The article outlines the main provisions for increasing the stability of the functioning of technological systems in complex and changing conditions of reconstruction, accepted as a system of conceptual, theoretical, and methodological foundations for the formation of their morphological appearance as adaptive dynamically transforming technological systems. Increasing the stability of the functioning of technological systems in complex and dynamic conditions of reconstruction is ensured by the implementation of strategies: A-strategy. Reduced dynamics of environmental conditions; B-strategy. Ensuring an increased level of homeostasis of the technological system in relation to the external environment and the dynamics of its states. The A-strategy is implemented at the stages of preparation for reconstruction and in the process of its implementation, and the B-strategy is implemented by the formation of a technological system that ensures its invariance with respect to changes in the states of the external environment and which is carried out by increasing the functional inertia of the system, functional and structural redundancy. The author called such systems adaptive dynamically transforming technological systems. Adaptive dynamically transforming technological systems are endowed, on the one hand, with the properties of astatic systems – as systems with variable morphology, capable of detecting purposeful adaptive behaviour while maintaining internal balance, and, on the other hand, with the properties of static systems – as high-performance specialized systems with states. Astatic properties ensure optimization of costs for transforming the morphology and function of a technological system, as well as limiting system states to the minimum possible level, and static properties optimize differential effects on a variety of characteristic production situations. The use of adaptive dynamically transforming technological systems allows us to resolve the fundamental parametric contradiction in building reconstruction technology – highly efficient and sustainable implementation of non-stationary construction processes in complex and changing conditions of building reconstruction.*

***Keywords: technology, reconstruction, theory of sustainable functioning, adaptive dynamically transforming, technological systems.***

**Introduction**. Reconstruction of buildings and structures, industrial and urban development involves the implementation of a complex of construction and installation works in conditions that can be characterized as complex and dynamic due to the presence of: dangerous and harmful industrial man-made factors that determine the need for special engineering and technical measures and work aimed at ensuring regulatory and safe conditions for construction and installation work, as well as imposing restrictions on possible methods, parameters and modes of execution and mechanization of construction processes; tightness of the construction site and passages to it, work areas and workplaces of workers; specific structure and volumes of work, characterized by a wide and very diverse nomenclature with a non-stationary distribution of volumes of work along the front - the presence of large, concentrated works at a time, along with low-volume, often dispersed volumes of work within an industrial complex, residential area, facility reconstruction or work front; a significant level of dynamics in the intensity and dynamics of the volume of work, due, firstly, to a significant variety of nomenclature, parameters and volumes of work, as well as the timing of their implementation, and secondly, to the discontinuity of work due to the requirements of the main industrial production, the conditions of urban reconstruction or technological considerations.

**Formulation of the problem**. The development of fundamental issues related to ensuring the effective and sustainable functioning of construction processes (hereinafter referred to as $S_{\text{o}}$-systems) in complex, dynamic conditions of reconstruction is relevant for solving the problem of further and significant increase in the efficiency of reconstruction of buildings.

Conceptually, this problem was first posed by the author in work [1] and found its resolution in his subsequent works [2–6].

**Main part.** The effectiveness of the functioning of the $S_{\text{o}}$-system depends on the type of system, the current states of the external environment and the dynamics of the states of the external environment [7–11].

If qualitative and quantitative assessments of the level of influence of a particular state of the external environment on the performance indicators of the $S_{\text{o}}$-system (production of workers, productivity and the boundaries of the effective use of mechanization means) have been sufficiently tested [12-15], then the nature of the influence of the dynamics of external environment on the functioning indicators of the $S_{\text{o}}$-system requires study.

To develop basic provisions aimed at maximizing the level of destabilizing influence of the external environment on the efficiency of functioning of the $S_{\text{o}}$-system, we will describe the internal processes in this system [16].

We will consider the general state of the system, the state of the controlled and controlling subsystem.

The general state of the $S_{\text{o}}$-system is functionally related to the input $B$, output $Y$ and internal $F$ parameters:

$$C = f(B, Y, F), \tag{1}$$

where $C$ – is the general state of the So-system;

$Y$ – is the actual result of the functioning of the system, characterizing its effectiveness;

$B$ – input parameters that are functionally related to the general goal and operating conditions of the $S_{\text{o}}$-system:

$$B = f(Q,\ \Lambda), \tag{2}$$

where $Q$ – is the overall goal of the system;

$\Lambda$ – conditions of the production situation formed by the external environment:

$$\Lambda = f(\Phi,\ \mathrm{X}), \tag{3}$$

where $\Phi$ – is a set of external certain factors (fixed and random factors that are not controlled - natural-climatic, regional, production, regulatory, etc.);

$\mathrm{X}$ – a set of external uncertain factors;

$F$ – a set of parameters that describe internal processes in the $S_\text{o}$–system, i.e. internal state:

$$F = f(C_A, C_B, Z), \tag{4}$$

where $C_A$, $C_B$ – state (a set of parameters that characterize the system's ability to solve the problems facing it), respectively, of the managed and control subsystems;

$Z$ – is a set of uncertain factors of the internal environment of the $S_\text{o}$-system.

A controlled subsystem (technological system – $S_\text{A}$-system) is a dynamic object that changes its internal state $C_\text{A}$ due to the presence of some internal processes of its functioning $G$ under the influence of the (external uncertain) environment $X$, as well as commands $U$ from the controlled subsystem:

$$C_A = f(X, U, G), \tag{5}$$

where $U$ – is a set of acceptable strategies for using active means (controllable factors):

$$U = f(Q, \Lambda, \ I), \tag{6}$$

where $I$ – is information about the parameters of the result $Y_n$, and the parameters of the internal state - the $S_\text{A}$ subsystem ($C_A$):

$$I = \{Y_n, C_A\}; \tag{7}$$

$G$ – internal processes (patterns) of the functioning of technical systems:

$$G = f(A_\text{a}, R_\text{a}), \tag{8}$$

where $A_\text{a}$ – is a set of elements of the $S_\text{A}$-system, which characterizes the quality indicators of active funds (productivity, number of elements, etc.);

$R_\text{a}$ – a set of connections.

The control $S_B$-system carries out control in accordance with the general goal of the So-system ($Q$), parameters of the external environment ($\Lambda$), as well as information ($I$) that comes from the controlled subsystem, guided by certain control principles ($P$).

Then, the state of the control subsystem ($C_\text{B}$) is described as follows:

$$C_\text{B} = f(Q, \Lambda, I, P). \tag{9}$$

The completed formalization of internal processes [16] that occur in the $S_o$–system makes it possible to develop basic conceptual provisions aimed at reducing the level of destabilizing influence of the external environment on the efficiency and sustainability of the $S_o$-system.

These provisions are based on the fact that when designing $S_o$-systems, as well as when planning its use, it is necessary to limit its diversity (Fig. 1) [16]:

$$H = \log_2 n \ , \tag{10}$$

where $H$ – is the diversity of the system (in this case it coincides with the measure of its disorder);

$n$ – is the number of different states of the system.

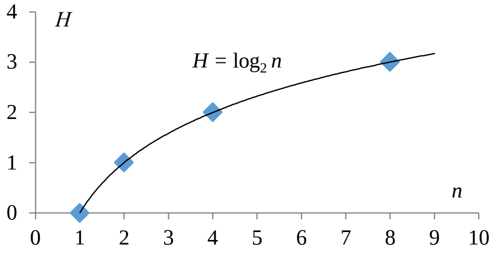

Fig. 1. Dependence of the diversity value of the $S_o$-system $H$ on the number of its states $n$

Limiting the variety of internal states of the system, i.e. a reduction compared to the abstractly possible $H \to H_a$, can be achieved as follows (strategies):

A-strategy. Decrease in the dynamics of the external environment;

B-strategy. Ensuring an increased level of homeostasis of the technological system in relation to the external environment and the dynamics of states; i.e. ensuring the basic parameters of the $S_A$-system (indicators of operational efficiency and quality of finished products) within certain limits during the interaction of the technological system with the external environment.

The noted strategies A and B are accepted as a general concept for increasing the sustainability of the functioning of technological systems in complex, dynamic conditions of reconstruction (Fig. 2).

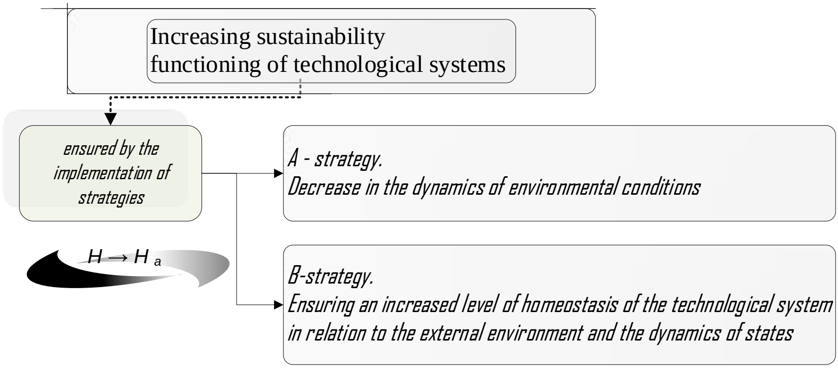

Fig. 2. Scheme of the general concept of increasing the stability of the functioning of technological systems in complex dynamic conditions of reconstruction [5–6]

Conceptual and theoretical foundations for the sustainable functioning of technological systems.

*A-strategy*. Reducing the dynamics of the state of the external environment must be carried out at all stages of reconstruction and preparation for it, where the process of forming and selecting solutions takes place [17]:

- preliminary reduction – at the stages of economic planning, design and organizational and technological preparation; that is, the search at the preliminary stages for more favorable production conditions, which are characterized by a lower level of pressure certain $(F)$ and uncertain $(X)$ factors and their dynamics $(D)$ on the system parameters;
- operational reduction – at the stages of construction and installation work; methods of using active means should influence the change in production situations in the required direction.

Moreover, if $\{\Phi, X\}, D \rightarrow min$, then $H_s \rightarrow min$, where $H_s$ is the variety of production situations (states of the external environment), which is also described by a logarithmic function (Fig. 3) of the form $H_s = \log_2 \eta$, where η – the number of states of the external environment – production situations [16].

It is obvious that not every change in the parameters of the external environment (state of the environment) can lead to a significant impact on the parameters of the technological system.

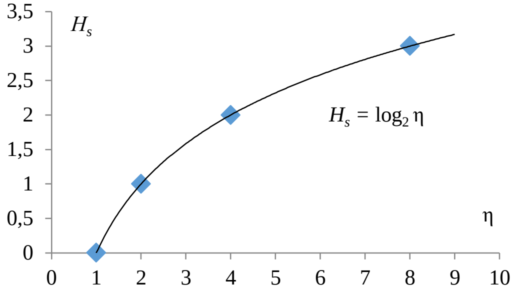

Fig. 3. Dependence of the magnitude of diversity of production situations $H_s$ on their number η

We are only interested in such changes in the external environment that change technological and organizational situations, that is, those that change production situations.

Thus, the dynamics of changes in the states of the external environment can be described as the rate of change in production situations during the calculation period: $D = \eta / t$, where $D$ is the dynamics of changes in the states of the external environment (the number of production situations η per unit of production time $t$).

The existence of dynamics of changes in the state of the external environment is confirmed by studies of the parameters of the work front during the reconstruction of industrial and civil facilities (Fig. 4).

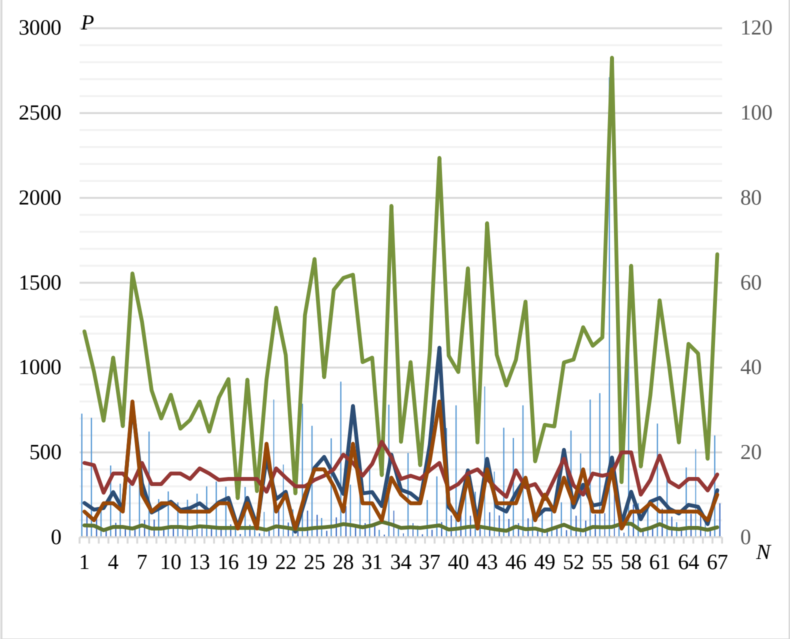

Fig. 4. Dynamics of technological parameters (*P*) of the work front using the example of replacing wooden floors of residential buildings during their reconstruction in the central historical part of the city of Kyiv (data collected from 67 representative objects, *N*) [5–6]:

🟦 Row 1 – volume of work at the site, $m^3$;
🟥 Row 2 – the number of dismantled and erected floors;
▨ Row 3 – number of sections within the tier;
🟨 Row 4 – the number of grips within the tier;
🟦 Row 5 – volume of work within the tier, $m^3$;
▬ Row 6 – volume of work on the site, $m^3$;
▬ Row 7 – volume of work on one gripper (shift intensity), $m^3$;
▬ Row 8 – concreting map size, $m^2$;
▬ Row 9 – volume of concreting map, $m^3$;
▬ Row 10 – number of concreting maps on the site, $m^3$

Consequently, at the stages of planning and economic, design and organizational and technological preparation of reconstruction, based on construction and technological analysis of work conditions and restrictions, a preliminary (design) reduction in the number of production situations ($\eta$) is carried out to an organizationally and technologically justified minimum $\eta_{\text{от}}^{min}$ according to the condition [16]:

$$\eta \rightarrow \eta_{\text{от}}^{min}. \tag{11}$$

Thus, the basis for the preliminary reduction in the dynamics of the external environment is the construction and technological analysis of the parameters and characteristics of the reconstruction and the synthesis of characteristic production situations based on a systematic approach, implemented by sequentially performed procedures (Fig. 5):

I. Systematic analysis and systematization of factors that determine the conditions and main features of construction and installation work during reconstruction with the development and justification of classification characteristics and categories;

II. Classification of objects and conditions of reconstruction, as well as the scope of work according to selected categories of complexity and dynamism of the scope of work.

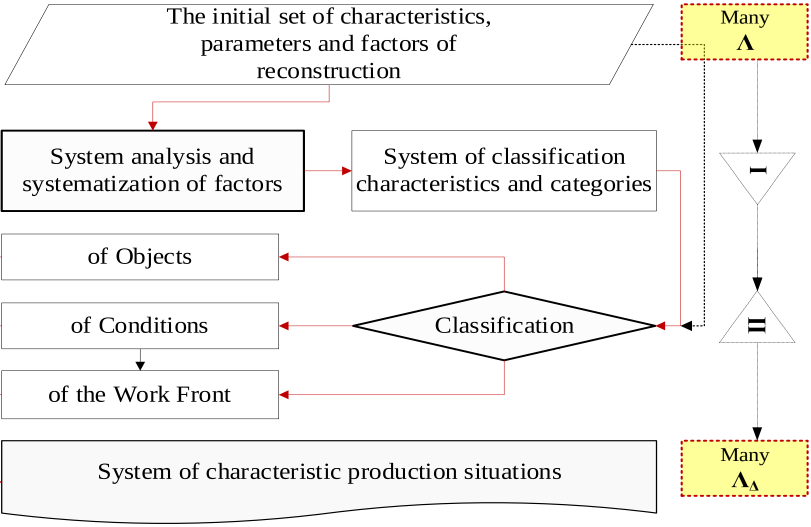

Fig. 5. Structural and logical diagram of the system formation characteristic production situations [5–6]

The result of system analysis and classification of objects, conditions and scope of work is a system of characteristic production situations that satisfies condition (11) and the condition [5–6]:

$$\{\Lambda_\Delta\} \ll \{\Lambda\}, \qquad (12)$$

where $\{\Lambda_\Delta\}$ – set of characteristic production situations;

$\{\Lambda\}$ – set of parameters and characteristics that determine the reconstruction conditions.

Methods of using active means ($S_A$-systems) should influence the change in production situations in the required direction – provide freedom of choice of decisions during the process [8–10].

The posed selection problem is connected, on the one hand, with the problem of forming a set of suitable physically implementable methods $U_п$, on the other hand, with the problem of choosing from a set of suitable methods a set of methods $U_a \in U_{\text{п}}$ (or at least one method) that are invariant to the operating conditions and are "flexible" in relation to existing uncertainties.

The second side of the problem is usually solved on the basis of the principle of adaptability (D. Gabor's principle of inconclusive decisions), which consists in the fact that at each stage of decision-making it is necessary to ensure freedom of decision-making in the future - to be able to compensate for unwanted deviations from the goal and efficiency [10] :

$$u^{id}(t,\tau) : \sup \Psi^t(u,\lambda,t,\tau),\ u(t) \in U_{\text{п}}(t,\tau), \tag{13}$$

where $u^{id}(t,\tau)$ – the best (ideal) method at time $t$ up to forecast errors for the forecast period τ;

$\Psi^t(u,\lambda,t,\tau)$ – the best value of the efficiency criterion under the conditions for choosing λ, which have developed at time $t$ on the set of acceptable (suitable) methods $U_{\text{п}}(t,\tau)$.

Thus, the basis for the operational reduction of the dynamics of the external environment is the development and justification of:

I. A variety of methods for producing construction and installation works that are suitable for reconstruction conditions and that are "flexible" in relation to existing uncertainties, by improving existing methods and developing new ones that are innovative (Fig. 6);

II. The general concept, methodology and organizational structure of monitoring the implementation of construction processes, aimed at obtaining and accumulating information and its operational (electronic) documentation to implement the principle of adaptability when making decisions.

The introduction of "flexibility" criteria (Fig. 6) for the conditions of the problem posed in the work consists in the selection and justification of rational parameters and the scope of application of production methods and mechanization of construction processes, with the establishment of the degree (level) of universality of technological solutions and methods according to the metric - specialized technology, multifunctional or adaptive.

*B-strategy*. Ensuring a higher level of homeostasis of the technological system ($S_{\text{A}}$–system) in relation to the external environment (Λ), as well as the dynamics of the states of the external environment ($D$) is carried out by strengthening internal functions (processes) in the $S_{\text{A}}$-system, when elements or connections between they are invariant to some transformations of the $S_{\text{A}}$-system or the external environment.

In efficiency theory and systems engineering [8–10], ensuring the invariance of the $S_{\text{A}}$-system with respect to changes (within certain limits) in the states of the external environment can be carried out:

a) increasing the functional inertia of the system;

b) functional redundancy;

c) structural redundancy.

*Functional inertia*, as a property of a technological system, characterizing its ability to allow interruptions in work without loss of output effect, can be increased by increasing the differential output effect of the system $Y_{\Delta}$ (that is, by reserving productivity $P_{\Delta}$) and (or) increasing operational time (by reserving time $T_{\Delta}$).

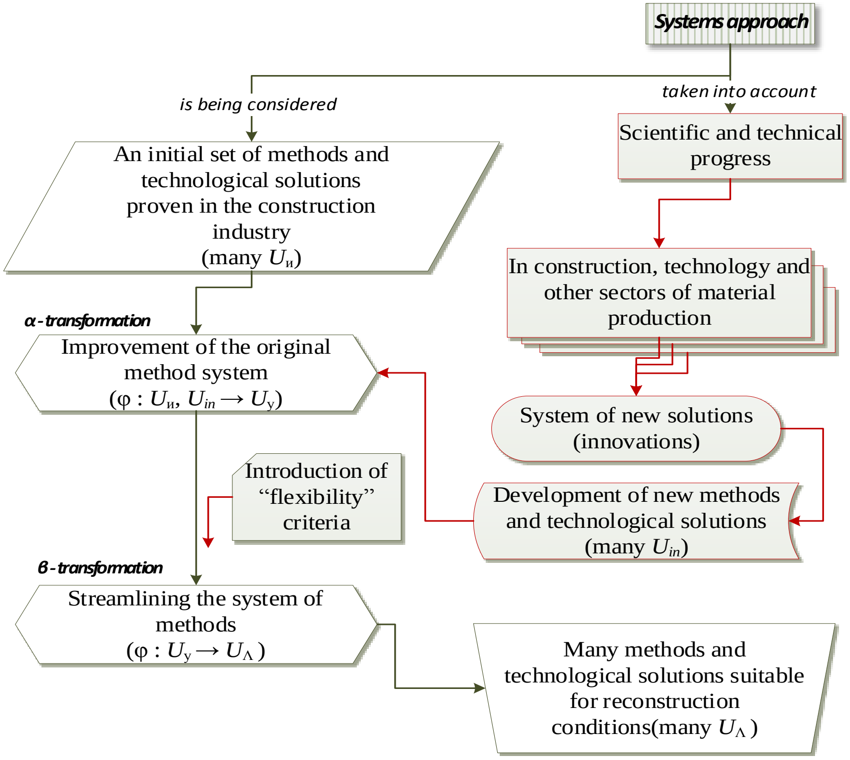

Fig. 6. Scheme for the formation
of a variety of suitable reconstruction methods [5–6]

In general, the functional inertia of a technological system ($S_A$ - system) can be formalized in the form of functional correspondence

$$\varphi\ :\ P_\Delta, T_\Delta\ \to Y_\Delta. \qquad (14)$$

*Functional redundancy* is redundancy using functional reserves. Useful technological functions (system properties) are taken as functional reserves, which the system is capable of effectively performing without loss of the output integral effect, and is formally presented in the form of functional correspondence:

$$\varphi\ :\ f_\Delta \to Y_\Delta,\ \ f_\Delta = \Phi(Q_i, t) \qquad (15)$$

where $f_\Delta$ – Δ–reserve target (useful) technological function of the $S_A$-system, existing at time $t$ and determined by the $i$-th system property $Q_i$ of the $S_A$-system with properties

$$(\forall_\Delta, S_A)\ [\exists!\ Q(S_A) = \{Q_i(S_A)\};\ i = 1, n], \qquad (16)$$

Thus, technological systems with functional redundancy are interpreted as multifunctional, universal systems that have a pre-designed set of system properties that implement one or another technological function.

*Structural redundancy* is redundancy using structural reserves that change the organizational and technological structure of a technological system ($S_A$-system). Structural redundancy is carried out by including adaptation means into the system that expand the capabilities of the technological system relative to it [5–6]:

- the main technological parameter - productivity (inclusion of an additional main or auxiliary machine in the kit);
- main technical characteristics (inclusion in the set of machines that increase (change) digging depth, feed, lifting height, etc.);
- basic technological functions (giving the concrete pump equipment for shotcrete, including an excavator with a hydraulic hammer in the set of earth-moving machines, including welding and installation manipulators in the concrete-laying complex, ensuring mechanized performance of reinforcement and formwork work).

In general, the structural redundancy of a technological system, like an $S_A$-system, can be formally described in the form of functional correspondence [5–6]

$$\varphi\ :\ \Delta A_{ai}, \Delta R_{\mathrm{ai}} \to K_i \to Y_\Delta;\ A_a \times R_a \to K\ , \qquad (17)$$

where $\Delta A_{ai}$ – $i$ – th reserve element of the SA system;

$\Delta R_{\mathrm{ai}}$ – $i$ – i is a backup connection;

$K_i$ – $i$ – i combination of structure, $K_i \in K$ ($K$ – set of possible combinations of structure, determined by the matrix $A\ :A_a \times R_a$.)

If we combine functions (15), (16) and (17) into a system of the form [5–6]:

$$\begin{cases} \varphi\ :\ P_\Delta, T_\Delta\ \to Y_\Delta, \\ \varphi\ :\ f_\Delta \to Y_\Delta,\ \ f_\Delta = \Phi(Q_i, t), \\ \varphi\ :\ \Delta A_{ai}, \Delta R_{\mathrm{ai}} \to K_i \to Y_\Delta;\ A_a \times R_a \to K, \end{cases} \qquad (18)$$

then we obtain a formal description of the technological $S_A$-system, *which has an unstable (changeable) structure*, capable of adapting its functions to a reasonable (design) set of production situations, and within these situations, maintaining efficiency indicators within acceptable values; due to the reservation of the output effect (functional inertia) and (or) functions (functional redundancy) and (or) structure.

The noted $S_A$-system will be characterized as *an adaptive dynamically transforming technological system*, capable of purposefully adapting its operating parameters to stochastic conditions and parameters of construction production in reconstruction conditions.

Then, the system property $Q_i$ of an adaptive dynamically transforming technological system ($S_A^D$-system) can be represented by the functional $\Phi_{\lambda i}$ from the system processes $F_{\lambda i}$ occurring in the system [5–6]:

$$Q_i = \Phi_{\lambda i}[F_\lambda(t), T];\ F_\lambda = \{F_{\lambda j}\},\ j = \overline{1, \mathrm{J}};\ F_{\lambda j}(t) = \Phi(Q_\lambda, t), \qquad (19)$$

where $F_{\lambda j}(t) = \Phi(Q_\lambda, t)$ - is the set of system processes generated by the $j$-th interaction of subsystems in the λ-th conditions of the production situation;

$Q_\lambda = \{Q_l\}, l = \overline{1, L_\lambda}$ – set of properties of all autonomous $L_\lambda$ subsystems in the λ conditions of the production situation;

$Q_l = \{Q_{lk}\}, k = \overline{1, K}$ – set of properties $l$ of the autonomous subsystem;

$k$ – property $l$ of an autonomous subsystem.

If μ variants of production situations are possible, then for the λ-th production situation (λ ∈ Λ)) we will have a set of $S_l$-subsystems of the $S_A^D$-system [5–6]

$$S_A^D = \{S_l\}, l = \overline{1, L_\lambda} \tag{20}$$

such that

$$(\forall_\lambda, S_{A\lambda}^D)\left[\exists!\ C_{A\lambda}^D, K_{A\lambda}^D \rightarrow Q_i = \left\{Q_i\left(S_{A\lambda}^D\right)\right\};\ i = 1, \Lambda;\ Q_i \cap Q_\lambda = \emptyset\right] \tag{21}$$

for all production situations (λ ∈ Λ)), there is a single state ($C_{A\lambda}^D$) and a combination of structure ($K_\lambda^D$) of the system that uniquely defines the only set of its system properties $Q_i$ such that in the set of system properties $Q_i$ and the set of properties of all subsystems $Q_\lambda$ there is not a single common element.

Thus, the $S_A^D$-system is a complex, holistic, open technological system with a dynamically transforming structure, with module elements and a system of adaptive stable connections that ensure targeted and operational transformation of its own morphology and target function in conditions of changing parameters of the technology of reconstruction of buildings and their complexes; and can be represented by *a generalized formal model* [5–6]:

$$\begin{cases} (\forall_\lambda, S_{A\lambda}^D)\left[\exists!\ C_{A\lambda}^D, K_{A\lambda}^D \rightarrow Q_i = \left\{Q_i\left(S_{A\lambda}^D\right)\right\};\ i = 1, \Lambda;\ Q_i \cap Q_\lambda = \emptyset\right], \\ S_A^D = \{S_l\}, l = \overline{1, L_\lambda}, \\ Q_i = \Phi_{\lambda i}[F_\lambda(t), T];\ F_\lambda = \left\{F_{\lambda j}\right\}, j = \overline{1, \mathrm{J}};\ F_{\lambda j}(t) = \Phi(Q_\lambda, t), \\ \begin{cases} \varphi\ :\ P_\Delta, T_\Delta \rightarrow Y_\Delta, \\ \varphi\ :\ f_\Delta \rightarrow Y_\Delta,\ f_\Delta = \Phi(Q_i, t), \\ \varphi\ :\ \Delta A_{ai}, \Delta R_{\mathrm{ai}} \rightarrow K_i \rightarrow Y_\Delta;\ A_a \times R_a \rightarrow K. \end{cases} \end{cases} \tag{22}$$

Thus, the basis for increasing the level of homeostasis of technological systems in relation to the external environment and the dynamics of states is:

I. Special methodology for the design and targeted application of adaptive technological systems, the formation of which is based on the principles of controlled dynamic transformations of organizational, technological and technical components - its own functional-morphological structure;

II. Basic conditions and methods for the reconstruction of buildings, industrial and civil development, ensuring the effective and sustainable implementation of construction processes in complex dynamic conditions of reconstruction.

In general, the above basic provisions for increasing the sustainability of the functioning of technological systems in complex, changing conditions of reconstruction (Fig. 7) are accepted as the theoretical foundations of their sustainable functioning, and which also underlie the methodology for the formation of their morphological appearance - as adaptive dynamically transforming technological systems.

**Conclusions**. Adaptive dynamically transforming technological systems ($S_A^D$) are endowed, on the one hand, with the properties of astatic systems – as systems with variable morphology, capable of detecting purposeful adaptive behavior while maintaining internal balance, and, on the other hand, with the properties of static systems – as high-performance specialized systems with states.

Astatic properties ensure optimization of costs for transforming the morphology and function of a technological system, as well as limiting system states to the minimum possible level, and static properties optimize differential efficiency in a design set of characteristic production situations.

The use of adaptive dynamically transforming technological systems allows us to resolve the fundamental parametric contradiction in building reconstruction technology – highly efficient and sustainable production of non-stationary construction processes in complex and changing conditions of building reconstruction.

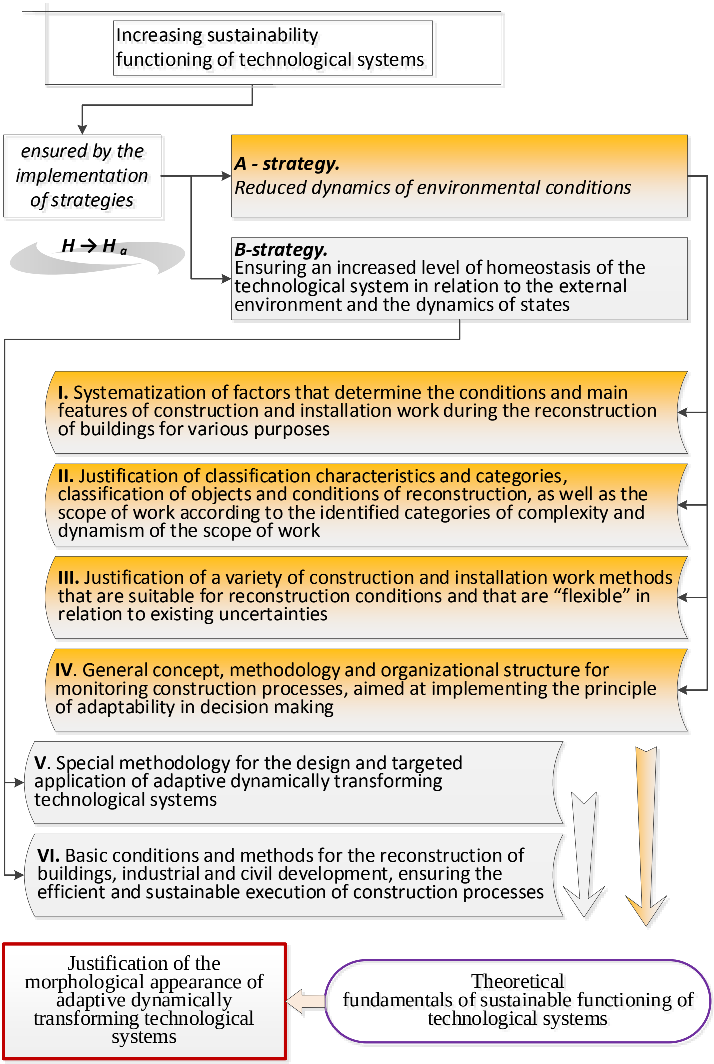

Fig. 7. Structural and logical scheme for the formation of theoretical foundations for the sustainable functioning of technological systems in complex, changeable conditions of reconstruction [5–6]

### *References:*

1. Osipov, A.F. (2000). Osnovnye principy proektirovaniya dinamicheski transformiruyushihsya tehnologicheskih sistem. *Prikladna geometriya ta inzhenerna grafika.* Vip. 67. P. 162–165.

2. Osipov, A.F. (2005). Zagalna koncepciya ta osnovni zakonomirnosti rozvitku skladnih virobnichih sistem v budivnictvi. *Mistobuduvannya ta teritorialne planuvannya*. Vip. 22. P. 219–230.

3. Osipov, A.F. (2013). Teoreticheskie osnovy ustojchivogo funkcionirovaniya tehnologicheskih sistem. *Mistobuduvannya ta teritorialne planuvannya*. Vip. 48. P. 321-328.

4. Osipov, A.F. (2015). Adaptivnye dinamicheski transformiruyushiesya tehnologicheskie sistemy rekonstrukcii zdanij. Usloviya primeneniya i strukturno-funkcionalnye urovni proektirovaniya. *Mistobuduvannya ta teritorialne planuvannya*. Vip. 57. P. 321-332

5. Osipov, A.F. (2016). Adaptivnye dinamicheski transformiruyushiesya tehnologicheskie sistemy. Metodologiya proektirovaniya organizacionno-tehnologicheskih reshenij rekonstrukcii zdanij: monografiya. K.: CP «Komprint». 364 p.

6. Osipov, A.F. (2022). Adaptivnye dinamicheski transformiruyushiesya tehnologicheskie sistemy. Metodologiya proektirovaniya organizacionno-tehnologicheskih reshenij rekonstrukcii zdanij: monografiya. 2-e izd. dop. i isp. K.: FOP Yamchinskij O.V.. 393 p.

7. Gusakov, A.A., Ginzburg, A.V., Veremeenko, S.A. at al (1994). Organizacionno-tehnologicheskaya nadezhnost stroitelstva. Red. A.A. Gusakova. M.: SvR-Argus. 472 p.

8. Gusakov, A.A. (1993). Sistemotehnika v stroitelstve. M.: Strojizdat. 368 p.

9. Druzhinin, V.V., Kontorov, D.S. (1985). Sistemotehnika. M.: Radio i svyaz. 200 p.

10. Reliability and efficiency in technology: Handbook: In 10 volumes / Ed. advice: V.S. Avduevsky (prev.) and others. M.: Mechanical Engineering, 1986. T. 1: Methodology. Organization. Terminology / Ed. A.I. Rembezy. 224 p.

11. Tomaev, B.M. (1983). Nadezhnost stroitelnogo potoka. M.: Strojizdat. 128 p.

12. Belyakov, Yu.I., Snezhko, A.P. (1988). Rekonstrukciya promyshlennyh predpriyatij. K.: Vysha shk.. 255 p.

13. Belyakov, Yu.I., Osipov, A.F., Akimov, F.N. (1991). Effektivnoe ispolzovanie betonoukladochnoj tehniki v stesnennyh usloviyah rekonstrukcii prompredpriyatij. *Mehanizaciya stroitelstva*. № 4. P. 23–25.

14. Belyakov, Yu.I., Romanushko, E.G., Osipov, A.. i dr.. (1986). Organizacionno-tehnologicheskie pravila proizvodstva betonnyh i zhelezobetonnyh rabot po ustrojstvu fundamentov i zaglublennyh sooruzhenij pri rekonstrukcii promyshlennyh obektov.K.: Minpromstroj USSR. 212 p.

15. Belyakov, Yu.I., Romanushko, E.G., Osipov, A.F. i dr. (1986). Organizacionno-tehnologicheskie pravila proizvodstva rabot po ustrojstvu buronabivnyh svaj pri rekonstrukcii prompredpriyatij. K.: Minpromstroj USSR. 96 p.

16. Osipov, A.F. (1998). Effektivnost funkcionirovaniya organizacionno-tehnologichesk ih sistem v usloviyah rekonstrukcii promyshlennyh predpriyatij. *Shlyahi pidvishennya efektivnosti budivnictva v umovah formuvannya rinkovih vidnosin*. Vip. 3. P. 120–122.

## *Список літератури:*

1. Осипов А.Ф. Основные принципы проектирования динамически трансформирующихся технологических систем. *Прикладна геометрія та інженерна графіка*. 2000. Вип. 67. С. 162–165.
2. Осипов О.Ф. Загальна концепція та основні закономірності розвитку складних виробничих систем в будівництві. *Містобудування та територіальне планування.* 2005. Вип. 22. С. 219–230.
3. Осипов А.Ф. Теоретические основы устойчивого функционирования технологических систем. *Містобудування та територіальне планування*. 2013. Вип. 48. С. 321-328.
4. Осипов А.Ф. Адаптивные динамически трансформирующиеся технологические системы реконструкции зданий. Условия применения и структурно-функциональные уровни проектирования. *Містобудування та територіальне планування*. 2015. Вип. 57. С. 321-332
5. Осипов А.Ф. Адаптивные динамически трансформирующиеся технологические системы. Методология проектирования организационно-технологических решений реконструкции зданий: монография. К.: ЦП «Компринт», 2016. 364 с.
6. Осипов А.Ф. Адаптивные динамически трансформирующиеся технологические системы. Методология проектирования организационно-технологических решений реконструкции зданий: монография. 2-е изд. доп. и исп. К.: ФОП Ямчинський О.В., 2022. 393 с.
7. Гусаков А.А., Гинзбург А.В., Веремеенко С.А. и др. Организационно-технологическая надежность строительства; под ред. А.А. Гусакова. М.: SvR-Аргус, 1994. 472 с.
8. Гусаков А.А. Системотехника в строительстве. М.: Стройиздат, 1993. 368 с.
9. Дружинин В.В., Конторов Д.С. Системотехника. М.: Радио и связь, 1985. 200 с.
10. Надежность и эффективность в технике: Справочник: В 10 томах / Ред. совет: В.С. Авдуевский (пред.) и др. М.: Машиностроение, 1986. Т. 1: Методология. Организация. Терминология / Под ред. А.И. Рембезы. 224 с.
11. Томаев Б.М. Надежность строительного потока. М.: Стройиздат, 1983. 128 с.
12. Беляков Ю.И., Снежко А.П. Реконструкция промышленных предприятий. К.: Выща шк., 1988. 255 с.
13. Беляков Ю.И., Осипов А.Ф., Акимов Ф.Н. Эффективное использование бетоноукладочной техники в стесненных условиях реконструкции промпредприятий. *Механизация строительства*. 1991. № 4. С. 23–25.
14. Беляков Ю.И., Романушко Е.Г., Осипов А.Ф. и др. Организационно-технологические правила производства бетонных и железобетонных работ по устройству фундаментов и заглубленных сооружений при реконструкции промышленных объектов. К.: Минпромстрой УССР, 1986. 212 с.
15. Беляков Ю.И., Романушко Е.Г., Осипов А.Ф. и др. Организационно-технологические правила производства работ по устройству буронабивных свай при реконструкции промпредприятий. К.: Минпромстрой УССР, 1986. 96 с.
16. Осипов А.Ф. Эффективность функционирования организационно-технологических систем в условиях реконструкции промышленных предприятий. *Шляхи*

*підвищення ефективності будівництва в умовах формування ринкових відносин*. 1998. Вип. 3. С. 120–122.

***О.Ф. Осипов***

### *Вступ до теорії сталого функціонування технологічних систем реконструкції будівель*

*У статті викладено основні положення підвищення стійкості функціонування технологічних систем у складних і мінливих умовах реконструкції, які приймаються як система концептуальних і теоретико-методологічних основ формування їх морфологічного вигляду як адаптивних технологічних систем, що динамічне трансформуються. Підвищення стійкості функціонування технологічних систем у складних та динамічних умовах реконструкції забезпечується реалізацією стратегій: А-стратегія. Зниження динаміки станів довкілля; В-стратегія. Забезпечення підвищеного рівня гомеостазу технологічної системи по відношенню до зовнішнього середовища та динаміки його станів. А-стратегія реалізується на етапах підготовки до реконструкції та в процесі її виконання, а В-стратегія - формуванням технологічної системи, що забезпечує її інваріантність по відношенню до зміни станів довкілля та здійснюється збільшенням функціональної інертності системи, функціональним і структурним резервуванням. Такі системи автор назвав адаптивні технологічні системи, що динамічне трансформуються. Адаптивні технологічні системи, що динамічне трансформуються, наділяються, з одного боку, властивостями астатичних систем – як систем з мінливою морфологією, здатних виявляти цілеспрямовану пристосовується поведінку при збереженні внутрішнього балансу, і, з іншого боку, властивостями статичних систем – як високопродуктивних спеціалізованих систем, що володіють станами.*

*Астатичні властивості забезпечують оптимізацію витрат за перетворення морфології та функції технологічної системи, як і обмеження станів системи до мінімально можливого рівня, а статичні властивості – оптимізують диференціальні ефекти на безлічі характерних виробничих ситуацій. Застосування адаптивних технологічних систем, що динамічно трансформуються, дозволяє вирішити фундаментальну параметричну суперечність у технології реконструкції будівель – високоефективне та стійке виконання нестаціонарних будівельних процесів у складних та мінливих умовах реконструкції будівель.*

***Ключові слова: технологія, реконструкція, теорія сталого функціонування, адаптивні динамічно трансформовані, технологічні системи.***

***Посилання на статтю:***

**APA:** Osipov, A.F. (2023). Introduction to the theory of sustainable operation of technological systems for building reconstruction. *Shliakhy pidvyshchennia efektyvnosti budivnytstva v umovakh formuvannia rynkovykh vidnosyn*, 52(1), 123-137.

**ДСТУ:** Осипов О.Ф. Вступ до теорії сталого функціонування технологічних систем реконструкції будівель. *Шляхи підвищення ефективності будівництва в умовах формування ринкових відносин*. 2023. №52(1). С. 123-137.