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# FUNDAMENTALS OF THE THEORY OF RESTORATION PROCESSES

***Introduction.*** *The development and justification of the modern fundamentals of the theory of restoration processes is a critical issue that enables continued innovation and improvement in the foundations of technology implementation and the methodology of organizational and technological design for the restoration of architectural monuments.*

***Problem Statement.*** *This process requires establishing a new system of logical principles for restoration, which includes fundamental provisions, assumptions, and organizational and technological constraints. This system, in its entirety, illuminates the core logic underlying the theory of restoration processes.*

***Purpose.*** *To substantiate the foundations of the theory of restoration processes by developing a system of principles and logical proofs tailored to the unique properties of both the object and subject of research — the architectural monuments and the processes of their restoration.*

***Materials and Methods.*** *A systematic and comprehensive approach has been employed, considering modern theories and principles of architectural restoration. The conceptual foundation is the indispensable requirement to ensure the authenticity of the object of restoration, whether the entire structure, its parts, or individual elements.*

***Results.*** *A system of theoretical propositions, assertions, and logical constructs describing the foundations of the theory of restoration processes for architectural monuments has been developed. The research confirms that the central logical element of this theory is the concept of a single, concurrent process of transformation, where both the material elements and the object of restoration are treated as a unified subject of work within the restoration process.*

***Conclusions.*** *The creation of the theoretical foundations for restoration processes applied to architectural monuments has enabled the organization of modern ideas, principles, and approaches into an open, internally differentiated, and cohesive system of knowledge. In this framework, the restoration process has been considered a specific sequence of actions for executing a complex set of restoration processes of varying complexity. The essence, structure, and established combinations of these processes have been determined by the system properties of the restoration object, the conditions under which the restoration is performed, and the existing organizational and technological constraints.*

*Keywords: theoretical foundations, restoration processes, restoration technology, architectural monuments.*

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For the sake of brevity, the construction processes carried out during the restoration of architectural monuments will be referred to here as "restoration processes."

The current foundation of restoration process theory is largely based on an extensive collection of empirical data, comprised of many documented facts. However, this foundation does not fully reveal the underlying nature of the processes and phenomena that occur within an architectural monument during restoration. Furthermore, it lacks sufficient proprietary rules and proofs (the theoretical foundation and logic of the theory remain incomplete). Much of the theoretical and applied knowledge in this area has been borrowed from other fields of construction, such as reconstruction, repair, or new construction, with only minimal adaptation to the specific characteristics of the object in question — namely, architectural monuments and the restoration processes they undergo.

The development of restoration process theory is intrinsically linked to the broader evolution of theoretical concepts regarding the restoration of architectural monuments. It is closely tied to both fundamental and applied research in the technology and methods used to organize construction work on buildings and structures designated as architectural monuments. Restoration process theory also intersects systematically and reciprocally with general construction theory and the fundamental principles of construction management. On one hand, it builds on the scientific foundation of industrial and civil construction technology and organization, adopting its primary theoretical and methodological principles as the starting point for restoration process theory. On the other hand, it adapts these principles to the specific needs of restoration.

The improvement of restoration process theory shall be continuous and sustainable, ensuring the timely incorporation of new empirical data, theoretical abstractions, and idealizations into the theoretical framework. This process of refinement also extends to the methodology of organizational and technological planning for restoration projects.

Various aspects of the development of theoretical concepts and principles for the restoration of architectural monuments, as well as the technologies and methods employed, have been explored by both domestic and international scholars [1—11], as well as in the author's previous works [12—16]. However, these and other studies do not address the critical scientific and practical issue of developing and justifying the fundamental principles of restoration process theory.

In accordance with modern views on science and technology [17], the fundamentals of restoration process theory should be seen as an open, internally differentiated, and integrated system of knowledge that possesses its own (see Fig. 1):

- Object and subject of study — architectural monuments and the processes involved in their restoration;
- Empirical foundation — a vast collection of documented facts;
- Theoretical foundation — a set of concepts, axioms, and idealizations describing the objects of the theory;
- The logic of the theory — rules and proofs;
- A set of propositions — the primary body of theoretical and applied knowledge.

Architectural monuments, as objects of restoration or have unique properties that define the key parameters of their restoration process, influenced by a multitude of factors — conditions under which restoration work is carried out.

The restoration processes, which are treated as the subject of research (both design and implementation), also possess distinct properties that differ from other types of construction, due to their unique logical essence specific to restoration.

An architectural monument, as a historical structure that has reached the point of restoration, exhibits a certain degree of preservation and technical condition. Depending on the chosen approach, it may undergo conservation, analytical restoration, synthetic restoration, or adaptive restoration. These restoration methods define the different types of restoration objects:

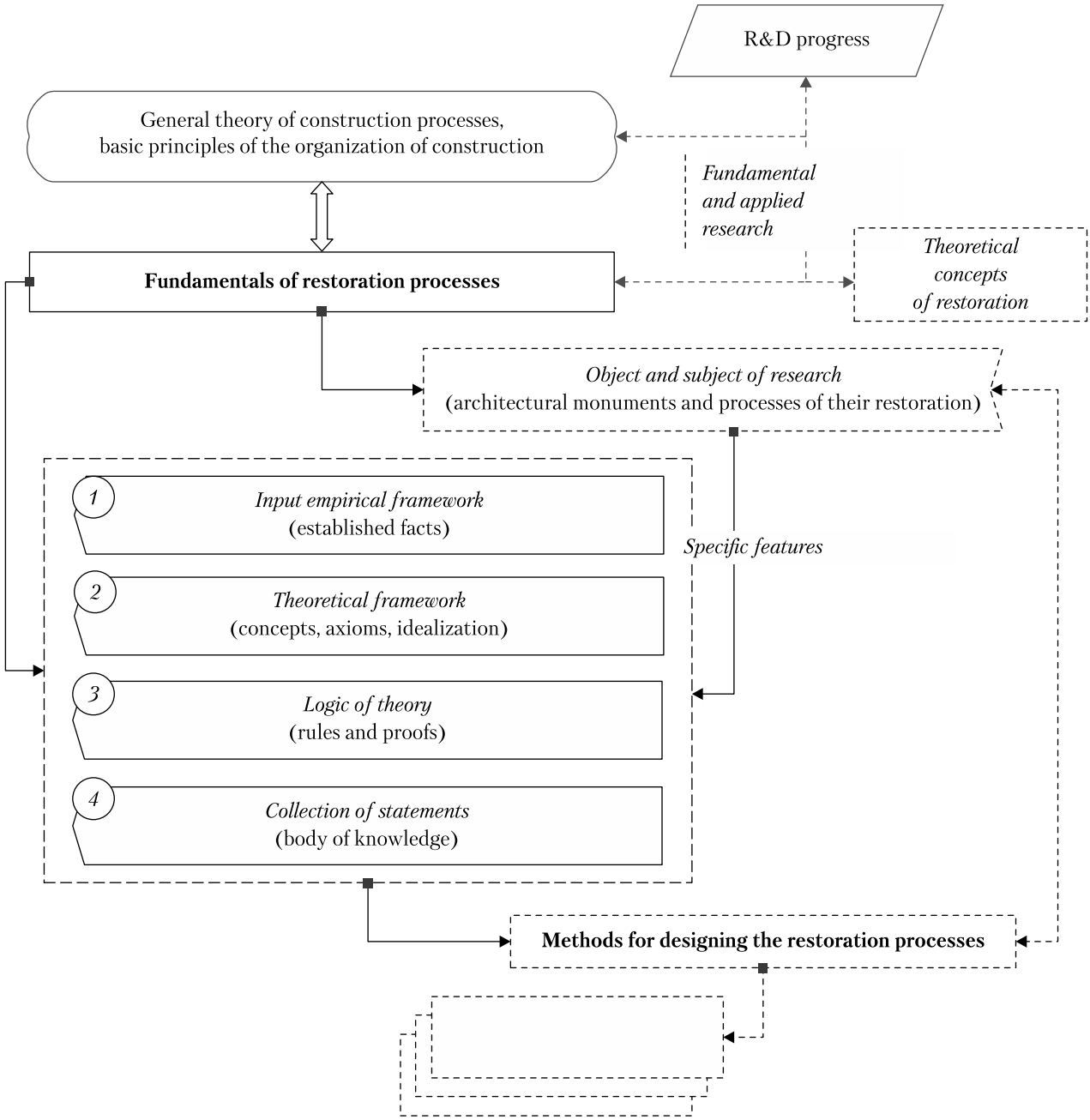


***Fig. 1.*** Structural logic relations of the fundamentals of restoration processes theory and its components

- *Conservation object*: an architectural monument in the process of being protected from further deterioration;
- *Analytical restoration object*: an architectural monument undergoing reinforcement of its ancient parts with minimal intervention and a limited scope of restoration work;
- *Synthetic restoration object:* an architectural monument in the process of near-complete reconstruction;

- *Adaptive restoration object:* an architectural monument being adapted for new purposes and functions.

Depending on the level of restoration complexity being designed, the restoration object can range from an architectural ensemble, a single monument, or any of its components — whether structural, engineering systems, or individual elements.

The unique properties of a restoration object, encompassing its various characteristics ($\langle x_i \rangle$): functional parameters (φ), construction technology (χ), preservation level (η), and technical conditions (ξ) and other parameters, may be considered to be its *systemic property* ($X_{or}$):

$$X_{or} = \langle x_i \rangle = f(\varphi, \chi, \eta, \xi, ...), \ (\langle x_i \rangle) \to \infty. \quad (1)$$

The systemic property of a restoration object is unequivocally determined by the properties of its constituent elements ($x_{ik}$): parts, individual structures, and structural elements:

$$X_{or} = \langle x_i \rangle = \begin{pmatrix} x_{i1} \\ x_{i2} \\ \cdots \\ x_{ik} \\ \cdots \\ x_{iK} \end{pmatrix}, \ i = (1, \mathrm{K}). \quad (2)$$

Eliminating the existing diversity of characteristics ($\langle x_i \rangle$) $\to \infty$ of a restoration object is achieved by constructing *new ideal objects — state categories of the restoration object* ($\kappa_j$). These categories collectively describe its systemic properties unequivocally and have a finite number, representing a set of categories of minimal scope; K → min:

$$X_{or} = \langle \kappa_j \rangle, \ \kappa_j \in \mathrm{K}; \ \mathrm{K} \to \min. \quad (3)$$

Any *change in the systemic properties* of the restoration object directly *influences the restoration process* ($S_{or}$), which refers to a specific sequence of restoration activities of varying complexity. The nature, structure, and established combinations of these activities are determined by the systemic properties of the restoration object ($X_{or}$), the conditions under which the restoration processes are carried out ($Y_r$), and existing organizational and technological constraints ($O_r$).

Thus, the restoration process can be mathematically formalized as a functional relationship:

$$S_{or} \to X_{or}, Y_r, O_r. \quad (4)$$

Each component of this functional relationship can be represented as a matrix of characteristic parameters, given expressions (2) and (3):

$$X_{or} = \langle \kappa_j \rangle, Y_p = \langle y_j \rangle = \begin{pmatrix} y_{j1} \\ y_{j2} \\ \cdots \\ y_{jh} \\ \cdots \\ y_{jH} \end{pmatrix}, \ O_r = \langle o_l \rangle = \begin{pmatrix} o_{l1} \\ o_{l2} \\ \cdots \\ o_{lp} \\ \cdots \\ o_{lP} \end{pmatrix}. \quad (5)$$

Any establishment of a specific sequence of restoration processes forms a corresponding restoration technology, each of which is based on an appropriate method. The method of restoration is determined by the principles underlying the formation of the restoration process, and its logical essence is defined by the characteristics that describe:

1. The integral (systemic) properties of the object of restoration ($X_{or}$), the conditions under which the restoration processes are carried out ($Y_r$), and the constraints imposed ($O_r$). These include:

- The category of architectural monument complexity, which gives rise to a group of restoration methods for monuments of moderate, medium, and high complexity.
- The category of structural strength and spatial stability of architectural monuments, which forms a group of methods for their restoration, such as recovery, reconstruction, reinforcement, restoration, and protection from further deterioration.

2. The properties of the elements ($x_{ik}$) of architectural monuments, specifically:

- The category of strength and stability of load-bearing structures, which forms a group of methods for restoring load-bearing structures.
- The category of rigidity and spatial stability of load-bearing frameworks, which forms a group of methods for restoring the rigidity and spatial stability of load-bearing frameworks.

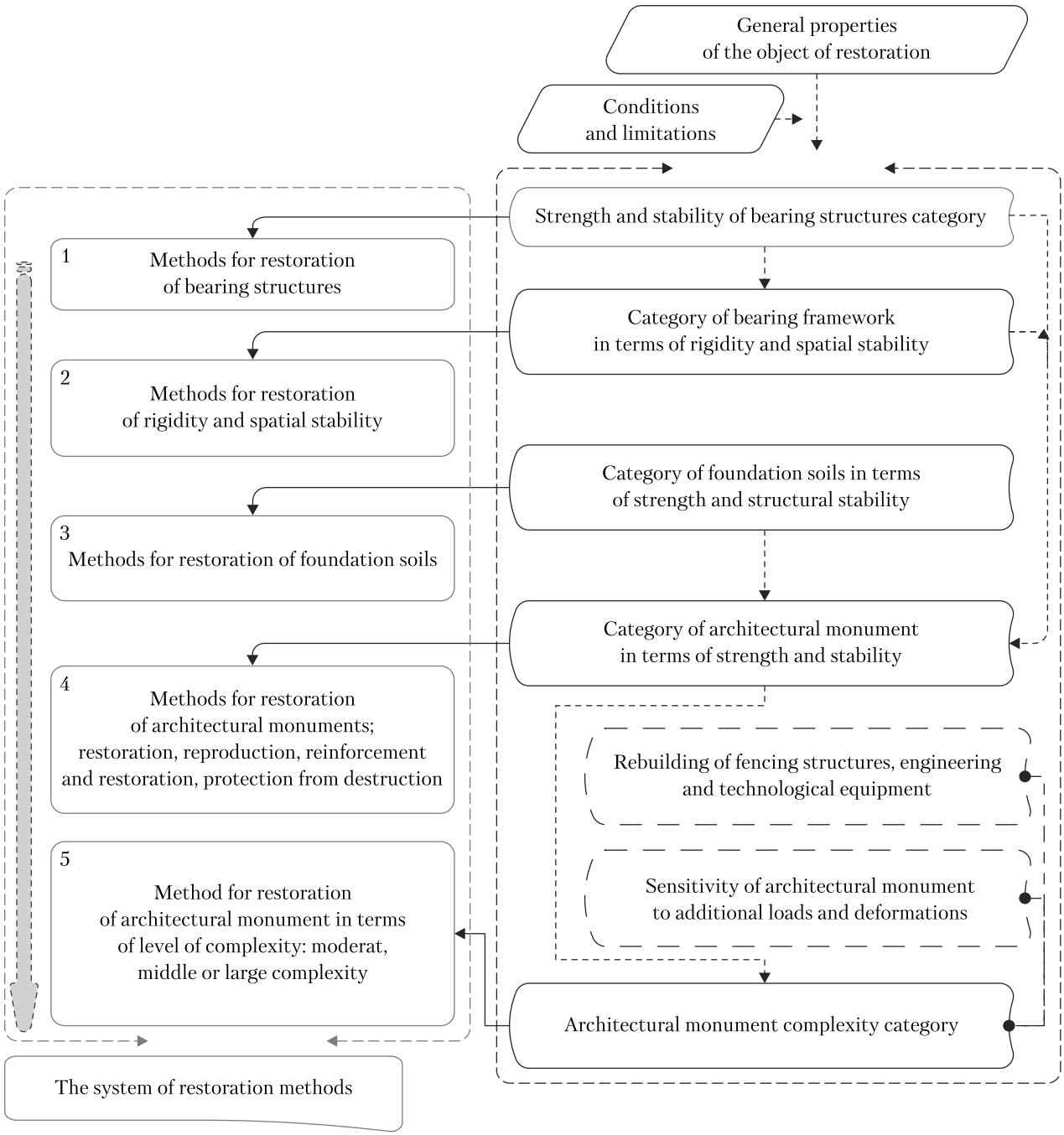


***Fig. 2.*** The system of the architectural monument restoration methods and their structural logic relations during the formation process

- The category of strength and structural stability of foundational soils, which forms a group of methods for restoring soil foundations.

The groups of methods discussed create the *overarching system of restoration methods* for architectural monuments (see Fig. 2).

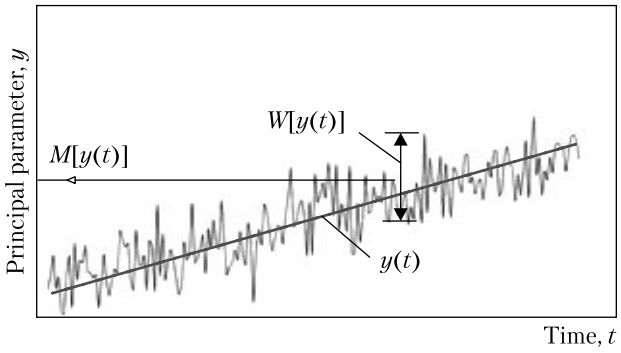


***Fig. 3.*** Interpretation of the non-stationarity of the restoration process with a deterministic trend (function $y(t)$ and the range of its fluctuations $W[y(t)]$

From the analysis of expression (5), it follows that the conditions under which restoration processes are performed ($Y_r$) and the organizational-technological constraints ($O_r$) are characterized by a high degree of variability and multiplicity.

Thus, the conditions under which restoration processes are carried out, along with the imposed constraints, collectively form highly complex and unique restoration conditions. These are primarily characterized by *the fragmentation, heterogeneity, and temporal discontinuity of the work front* ($_{sis}F$), which is perceived as its *dominant and overarching characteristic*.

The mastery of this work front, given its general characteristic, logically dictates the overall property of the restoration processes ($_{sis}S_o$): their *non-stationarity, multiplicity, and heterogeneity.*

*The non-stationarity* of the restoration process ($^{ast}S_o^i$) manifests itself in the variability of its primary parameters (duration, intensity, productivity) over time. The restoration process is considered a non-stationary process with a deterministic trend, so its magnitude is forecasted as the mathematical expectation $M[y(t)]$ at a given time $t$, which belongs to the project interval [0, $T$] (see Fig. 3). Formally, this can be expressed as a functional representation:

$$^{ast}S_o^i \to y(t) = M[y(t)],\ t \in [0,\ T]. \qquad (6)$$

*The multiplicity* of restoration processes ($^{asd}S_o^i$) manifests itself in the presence of a significantly broader range of preparatory $^{asd}s_o^{pr}$, auxiliary $^{asd}s_o^{au}$ and primary $^{asd}s_o^{pri}$ processes, such that

$$^{asd}S_o^i \to \underbrace{^{asd}s_o^{pr},\ ^{asd}s_o^{au},\ ^{asd}s_o^{pri}}_{\uplus} \to \infty. \qquad (7)$$

*The heterogeneity* of restoration processes ($^{arod}S_o^i$) manifests itself in the simultaneous combination of a large number of restoration processes with varying technological characteristics and levels of complexity. This leads to a substantial increase in their diversity ($H$), which tends toward infinity:

$$^{arod}S_o^i \to H = \log_2 n \to \infty, \qquad (8)$$

where $H$ is the measure of diversity of the restoration processes; $n$ is the number of restoration processes of various essence and complexity.

If we combine expressions (6), (7), and (8), we obtain a formal description of *the systemic property of restoration processes* ($_{sis}S_o$):

$$_{sis}S_o = (^{ast}S_o^i,\ ^{asd}S_o^i,\ ^{arod}S_o^i) \to {}_{sis}F \qquad (9)$$

provided that

$$\begin{cases} ^{ast}S_o^i \to y(t) = M[y(t)],\ t \in [0,\ T], \\ ^{asd}S_o^i \to \underbrace{^{asd}s_o^{pr},\ ^{asd}s_o^{au},\ ^{asd}s_o^{pri}}_{\uplus} \to \infty. \\ ^{arod}S_o^i \to H = \log_2 n \to \infty \end{cases} \qquad (10)$$

The systemic properties of the restoration object $\xi_{or}$ (see (1)) alter the conventional concept of labor processes. In the restoration of architectural monuments, the overall set of labor processes forms two hierarchical groups (see Fig. 4):

- *The first group* consists of restoration labor processes, corresponding to simple and complex restoration processes.
- *The second group* includes conventional labor processes, which correspond to work operations and work movements.

This division of restoration processes into two groups serves as the conceptual foundation for implementing the most critical condition of restoration — the imperative to ensure the authenticity of the restoration object, its parts, or elements. This is accepted as the $\alpha$-*criterion* ($\alpha$).

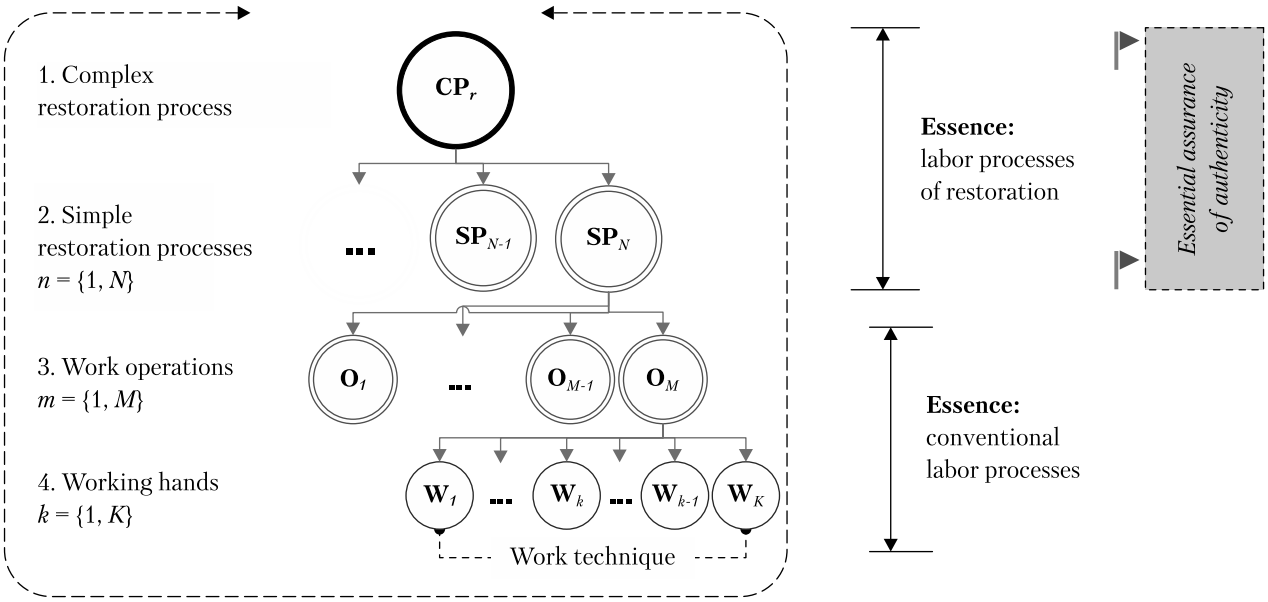


***Fig. 4.*** Breakdown of a complex restoration process ($\mathbf{CP}_r$) by the components: $\{\mathbf{SP}_n\}$ is the set of simple restoration processes; $\{\mathbf{O}_m\}$ is the set of work operations; and $\{\mathbf{W}_k\}$ is the set of work movements

At these hierarchical levels — simple and complex restoration processes — the aforementioned α-criterion is introduced. This criterion alters the methods and modes of executing work operations and simple restoration processes. It ensures that within the set of possible methods for their execution ($M_p^i$), there is no method ($^{\not\alpha} m_p^i$) that does not meet the α-criterion:

$$M_p^i = \{m_p^i\} \to \alpha;\ i = (1, M) \qquad (11)$$

provided that

$$\{^{\not\alpha} m_p^i\} = \varnothing.$$

The object of restoration, as a historical structure, fundamentally alters the logical essence of the processes involved in its transformation. In line with the general theory of construction processes formulated by Professors V. K. Chernenko and O. F. Osipov [18], *the logical essence* of construction processes is understood as the presentation of the construction process as a unified and interdependent set of purposeful actions aimed at *transforming material elements into a construction product*.

Thus, *the central logical element* of the theory of restoration processes is *the concept of a unified, concurrent transformation* of material elements (ME) and the object of restoration (OR), which are considered together as the single object of labor (OL) in the restoration process (see Fig. 5).

Any unified, concurrent transformation $P_j$ from the set of possible transformations $P_j \in \{P_j\}$ can be associated with a unique pair of interrelated changes in the states of both the material elements ($St_l \to St_n$) and the object of restoration ($St_z \to St_m$):

$$\left(\forall, P_j\right)\left[\exists!\begin{cases}\left(St_l \to St_n\right), \\ \left(St_z \to St_m\right)\end{cases}\right]. \qquad (12)$$

*The second logical element* of the natural-scientific foundation of the theory of restoration processes is the concept of the product of the restoration process. Its designed property $C^{rp}$ is formed through the interrelated and concurrent transformation of *the initial properties of both the object of restoration and the material elements*. This can be expressed as $(C^l \to C^n) \cup (C^z \to C^m)$, where the final *unified property* $C^{rp} = \{C^z\} \cup \{C^l\}$ is created by the simultaneous change of both sets of characteristics.

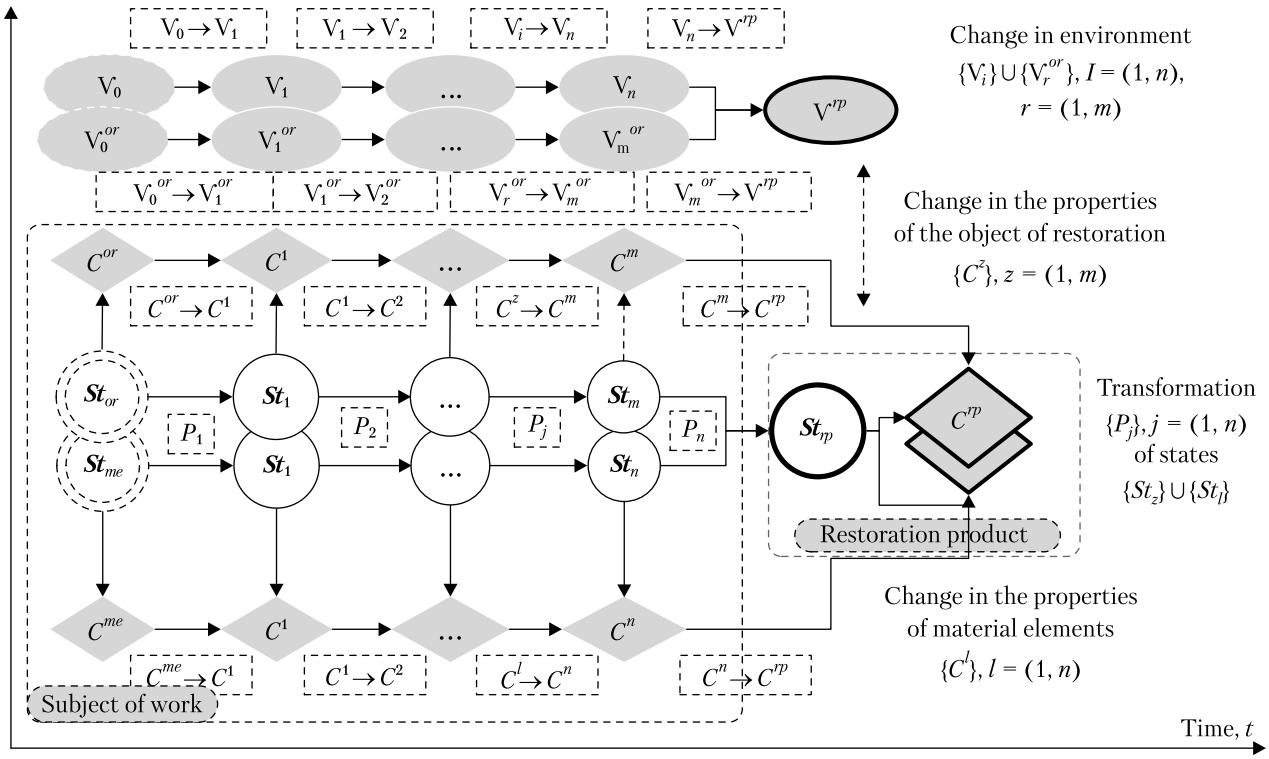


***Fig. 5.*** The process of creating the restoration product can be understood as a set of simultaneous and coordinated transformations $\{P_j\}$ applied to the object of labor across the combined set of states of the material elements (ME) and the restoration object (OR), represented as $St_z \cup St_l$. This process also involves external influencing factors $\{V_i\} \cup \{V_r\}$.

For any single simultaneous transformation $P_j$ from the set of possible transformations $P_j \in \{P_j\}$, a corresponding pair of interrelated changes can be defined: the change in the properties of the material elements ($C^l \to C^n$) and the change in the properties of the restoration object ($C^z \to C^m$):

$$\left(\forall, P_j\right)\left[\exists!\left\{\begin{array}{l}(C^l \to C^n),\\ (C^z \to C^m)\end{array}\right.\right]. \qquad (13)$$

The initial properties of the material elements ($C^{me}$) correspond to the respective properties of the restoration object ($C^{or}$). However, the process of changing these properties occurs through *their own phenomenological processes* $\Phi^l = \{\varphi^l\}$ and $\Phi^z = \{\varphi^z\}$, which govern the transformation of the properties of both the material elements and the restoration object:

$$\left\{\begin{array}{l} C^{me} \leftrightarrow C^{or},\\ \forall_v, C^l, C^z\left[\begin{array}{l}\exists!\ \Phi^l = \left\{\varphi^l\right\}; l = \overline{1, n};\\ \Phi^z = \left\{\varphi^z\right\}; z = \overline{1, m};\ \varphi^l \cap \varphi^z\end{array}\right]\end{array}\right. . \qquad (14)$$

*The third logical element* of the scientific essence of the theory of restoration processes is that the conditions under which they are carried out are determined by a combined set of influencing factors $\{V_i\} \cup \{V_r\}$ that establish:

*First,* the general environmental conditions — including natural-climatic, atmospheric, production, and organizational-technological factors $\{V_i\}$;

*Second*, the specific restoration conditions — defined by functional-purpose and construction-technological factors and limitations $\{V_r\}$.

Thus, for any single concurrent transformation $P_j$ of the state of the object being worked on, there

corresponds a paired set of interdependent changes in the external environment — representing the factors that influence the process:

$$\left(\forall, P_j\right)\left[\exists!\left\{\begin{array}{c}(V_i \to V_n),\\ (V_z^{or} \to V_m^{or})\end{array}\right]\right. . \qquad (15)$$

By combining expressions (12), (13), (14), and (15), we obtain a *theoretical model of the restoration process*. This model reveals the scientific essence of the processes and phenomena underlying the restoration:

$$\left(\forall, P_j\right)\left[\exists!\left\{\begin{array}{l}\left(St_l \to St_n\right);\\ \left(St_z \to St_m\right);\\ (C^l \to C^n);\\ (C^z \to C^m);\\ (V_i \to V_n);\\ (V_z^{or} \to V_m^{or})\end{array}\right]\right. \qquad (16)$$

provided that:

$$\left\{\begin{array}{c} C^{me} \leftrightarrow C^{or},\\ \forall_v, C^l, C^z\left[\begin{array}{l}\exists!\ \Phi^l = \left\{\varphi^l\right\}; l = \overline{1, n};\\ \Phi^z = \left\{\varphi^z\right\}; z = \overline{1, m};\ \varphi^l \cap \varphi^z\end{array}\right]\end{array}\right. . \qquad (17)$$

Thus, it can be asserted that the restoration process as a whole represents a unified and interrelated set of purposeful actions aimed at the simultaneous transformation of both material elements and the restoration object into the final product of the restoration process. The central logical element of the theory of restoration processes is the concept of a single, simultaneous transformation of material elements and the restoration object, which are treated as a single subject of labor in the restoration process.

The overarching characteristic of the restoration work front is its fragmentation, heterogeneity, and temporal discontinuity, while the general property of restoration processes is their non-stationarity, multiplicity, and diversity.

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ОСНОВИ ТЕОРІЇ РЕСТАВРАЦІЙНИХ ПРОЦЕСІВ

**Вступ.** Розробка та обґрунтування сучасних основ теорії реставраційних процесів є актуальним питанням, що дозволяє забезпечити подальший інноваційний розвиток та вдосконалення основ технології виконання та методології організаційно-технологічного проєктування процесів реставрації пам'яток архітектури.

**Проблематика.** Це потребує встановлення нової системи логічних сутностей реставраційного процесу, фундаментальних положень, припущень та організаційно-технологічних обмежень. Ця система у власної сукупності висвітлює основну логіку теорії.

**Мета.** Обґрунтувати основи теорії реставраційних процесів із власною системою правил і доказів, яка є адаптованою щодо особливих властивостей об'єкта та предмета дослідження — пам'яток архітектури та процесів їхньої реставрації.

**Матеріали й методи.** Використано системні комплексні дослідження з урахуванням сучасних уявлень та принципів реставрації пам'яток архітектури, концептуальним підґрунтям є неодмінне забезпечення справжності об'єкта реставрації, його частини або елемента.

**Результати.** Створено сукупність теоретичних положень, тверджень та логічних побудов, що описують основи теорії реставраційних процесів при реставрації пам'яток архітектури. Доведено, що центральним логічним елементом теорії реставраційних процесів є уявлення про єдиний спільно-одночасний процес перетворення матеріальних елементів та об'єкта реставрації, які розглядаються як єдиний предмет праці реставраційного процесу.

**Висновки.** Створення основ теорії реставраційних процесів, що здійснюються під час реставрації пам'яток архітектури, дозволило упорядкувати сучасні уявлення, принципи і підходи щодо технології та організації реставрації у відкриту, внутрішньо диференційовану та цілісну систему знань, в якій процес реставрації розглядається як певний порядок виконання комплексу реставраційних процесів різної складності, сутність, структура та встановлені комбінації якого визначаються системними властивостями об'єкта реставрації, умовами виконання реставраційних процесів та існуючими організаційно-технологічними обмеженнями.

*Ключові слова:* основи теорії, процеси реставрації, технологія реставрації, пам'ятники архітектури.