

**Mishchenko V.Ya.
Chechin K.A.**



**Mishchenko
Valery Yakovlevich,**

Doctor of Technical Sciences,
Professor of Department
of Construction Organization and
Real Estate Management;
Moscow State University
of Civil Engineering (National
Research University) (MGSU);
26 Yaroslavskoe shosse, Moscow,
129337, Russian Federation
ID RSCI: 386458,
Scopus AuthorID: 57195990417,
WoS ResearcherID: AAB-9505-2019,
ORCID: 0000-0003-2385-5426;
oseun@yandex.ru



**Chechin
Kirill Aleksandrovich,**

Postgraduate student of Department
of Construction Organization
and Real Estate Management;
Moscow State University
of Civil Engineering (National
Research University) (MGSU);
26 Yaroslavskoe shosse, Moscow,
129337, Russian Federation;
SPIN-code: 9428-9349;
chech.kirill@yandex.ru

Positive emergent effect in post-collapse building restoration systems

The paper examines the phenomenon of positive emergence within the synergistic system of construction and restoration works following building collapses caused by significant natural or man-made impacts. Emergence is defined as the manifestation of qualitatively new, previously unpredictable system properties leading to the enhanced performance of the object. The post-earthquake restoration of the Italian village of Venzone (1976) serves as a case study, demonstrating how a disaster can catalyze improvements in architectural integrity, functionality, and socio-economic value through adaptive reconstruction. A probabilistic-statistical model for predicting the Positive Emergence Effect (PEE) is developed, incorporating key influencing factors: project team competence, flexibility of design solutions, sufficiency of resources, and the architectural improvement potential of the project. Under favourable conditions, the baseline probability of PEE is estimated to exceed 17 %. The model is then refined by introducing the critical important risk factor of latent defects undetected during the initial technical survey. Accounting for this factor significantly reduces the predicted PEE probability, highlighting the paramount importance of comprehensive pre-project examination and uncertainty management. The practical value of the research lies in justifying adaptive project design and flexible management approaches to realize the emergent potential in post-collapse restoration. The proposed framework provides a basis for developing compensatory measures against unforeseen complications. The research concludes that a positive emergent effect should be considered a valuable target in reconstruction planning, capable of transforming a recovery process into an opportunity for holistic systemic enhancement of the building across technical, economic, and sociocultural dimensions.

Keywords: *emergence, post-collapse restoration works, synergy, probabilistic forecasting, flexibility of design solutions, hidden defects*

INTRODUCTION

The execution of construction and restoration works (CRW) on buildings after sustained damage relies on clear planning, regulations, and standards. The issue of reviving cities after devastating military conflicts and natural disasters has been studied by P.P. Oleinik, A. Maaruf, E.V. Shcherbina, A. Belal and M. Hrasnica. Based on the results of the research work by B.F. Shirshikov and V.V. Akulich, it can be unequivocally concluded that CRW encompasses all types of general construction and specialized works and can have the character of either major repairs or reconstruction, depending on the degree of damage sustained. Some features of restoration works can be distinguished [1]:

- specific types of works with their own non-standard technology;
- the composition and scope of works depend on the spatial planning solutions of buildings and structures, the degree of their damage, the sequence of restoration works, and the concentration of restoration works on the object and within a group;
- the structure of CRW, its non-repeatability;
- the possibility of forming and operating specialized mobile mechanized columns for performing individual types of works by integrated teams;
- changes in the work structure, the ratio of specific weights of various types of works in the total volume of construction and installation works. The restoration of any building is sharply different from the work ratios in its new construction;

- the absence of standard and ready-made solutions, as well as all necessary regulations for CRW.

Under conditions of uncertainty arising from emergencies involving real estate objects, there is a need for rapid forecasting of the probability of possible scenarios, namely further consequences, both positive and negative, in terms of their impact on the object under consideration. Probabilistic forecasting is defined by the post-nonclassical scientific paradigm, which has become most relevant in modern society [2].

Construction and restoration work (CRW) collectively constitute a complex construction system, comprising various defined and variable parameters. The CRW organization system after a collapse is a typical synergistic system, characterized by its components such as a high degree of uncertainty, internal and external interactions, and the capacity for adaptation and self-organization. The application of synergy principles allows for more flexible and effective management of this complex process (Fig. 1).

Emergence in this context is understood as a qualitatively new property of a system arising from the interaction of its components, not initially embedded in the design. We will consider this effect from the perspective of old construction objects' systems acquiring, as a result of forced changes and modernization, new aggregate qualities.

Let's consider a vivid example of European experience in restoring an entire village after a natural disaster.

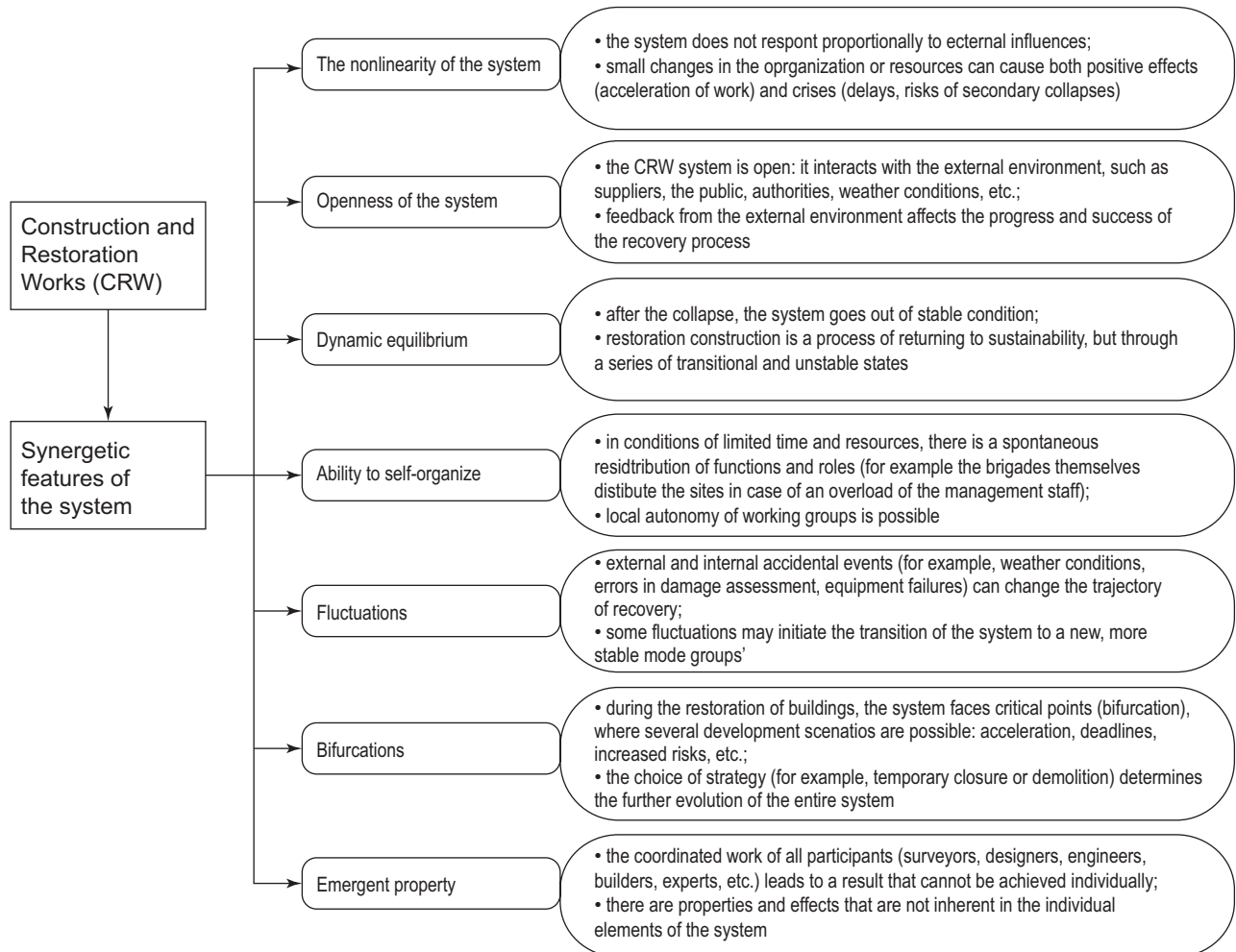


Fig. 1. Main features of synergy in the CRW organization system

THE VILLAGE OF VENZONE IN THE ITALIAN PROVINCE OF UDINE (HISTORICAL MUSEUM OF MUMMIES)

On May 6, 1976, a devastating earthquake occurred in the Friuli-Venezia Giulia region in northeastern Italy, completely destroying the village of Venzone in the province of Udine [3]. Large-scale restoration works of the village's historical buildings and architectural monuments began shortly thereafter. The city committee decided to reuse suitable stone fragments from the destroyed buildings in the restoration and construction. During the meticulous process of collecting and sorting stones, over 10,000 stones from the destroyed buildings were preserved, stored, and cataloged for reuse in reconstruction. The reconstruction of Venzone was completed in 1990. Today, it is hardly noticeable that most buildings were rebuilt in the last few decades [3].

The restoration of the historical buildings led to Venzone being recognized as the most beautiful village in Italy in 2017 based on the results of the national television competition "Il Borgo dei Borghi", surpassing 19 rival contenders. The winner received special recognition from the judges as the best example of architectural and artistic restoration after an earthquake¹.

¹ Venzone vince l'edizione 2017 Concorso "Borghi". Corriere della Sera. 17 aprile 2017. URL: https://www.corriere.it/cronache/17_aprile_17/venzone-vince-l-edizione-2017-concorso-borgo-borghi-032ab05c-236e-11e7-9fca-ec0025fa502c.shtml

In the reconstruction of Venzone, one can note the acquired positive emergent effect in the form of widespread global publicity after winning the competition, a significant increase in tourism levels, and the strengthening of the local economy (Fig. 2, 3)².

Unlike new construction design, the organization system, for example, for reconstruction after destruction, must possess properties of flexibility, creativity, and adaptation "on the go", which determines its viability. It is precisely under these conditions that the potential for positive emergence arises. The forecast of obtaining a positive effect can be calculated using statistical mathematical analysis.

The concept of emergence pertains to systems theory, defined by the rule "the holistic property of a system is greater than the sum of the properties of all its individual elements". The presence of generated properties specific to the system and not derivable from the known properties of the system's elements and the ways they are combined into subsystems is emergence [4, 5].

Experience in organizing construction works shows the emergent structure of relationships between elements and subsystems of each system. Subsystems cannot function autonomously; they interact in such a way that the properties of a subsystem depend on

² URL: <https://new.unarussainitalia.ru/srednevekovyy-vencone-i-ego-muzey-mum.html>



Fig. 2. Fountain in the square



Fig. 3. The main cathedral of Venzone

Table 1. Positive consequences of the emergent effect

Aspect	Before reconstruction	After reconstruction	Effect
Functionality	Outdated planning solutions	New public spaces, atrium, translucent structures	<ul style="list-style-type: none"> the flexibility of the system of planning solutions and space, increasing the safety margin of building structures can significantly expand the possibilities of application and purpose of the building;
Energy Efficiency	Low	Enhanced by the use of the latest materials with an increased coefficient of heat transfer resistance	
Architectural expressiveness	Standardized historical	Integration of new materials and architectural solutions into the historical framework. A unique blend of old and new	<ul style="list-style-type: none"> reduced load on heating and air conditioning systems contributes to a significant reduction in the size of engineering systems, consequently freeing up usable volume, and the systems themselves are easier to conceal;
Structural strength	Heterogeneous, partially weakened	Reinforced with innovative materials	
Social significance and identity	Low level of importance, appearance is repulsive	The updated visual appearance acquires a unique symbiosis of qualities already historically familiar with the updated and modern, the level of social attractiveness is high	<ul style="list-style-type: none"> the system of integrating modern materials into the historical foundation and design, considering current societal needs, allows achieving a high level of social significance

the totality of interconnections with other elements and the quantitative measure of these interconnections. The actual operational parameters of an engineering structure (service life, maintenance costs, etc.) often diverge significantly from their design values, which were forecasted based on calculation schemes of individual subsystems and elements prior to their integration. The emergence of a system does not allow limiting oneself to studying its elements and the connections between them but also requires conducting a holistic analysis of the complex system. The patterns of generated (emergent) properties are the most complex to observe, qualify, quantify, and forecast, requiring constant monitoring of the system's lifecycle, analysis of all available information about the object, and the development of situational support for the system's development [4].

Key characteristics of the emergent effect:

- unpredictability: the inability to foresee at the design stage all positive and negative consequences for the implementation object;
- wholeness: the overall property of the system surpasses the sum of its components;
- contextuality: it depends on specific conditions (social, technical, environmental).

Also, it is necessary to highlight the possible positive consequences of the effect, indicated in Table 1.

We have defined the goals of such projects aimed at obtaining positive emergent effects, and to achieve any goal, specific tasks must be set. Regarding construction and restoration works, it is first necessary to consider the tasks that will be set at the stages of inspection and design [6].

The experience of post-disaster recovery, described in other studies, confirms and specifies the key conditions for the emergence of positive emergence in construction and restoration works (CRW). Analysis of works dedicated to damage assessment and reconstruction strategies shows that unpredictability and the necessity for adaptation are not obstacles, but potential sources of systemic improvements.

In the context of damage and hidden defect assessment, the study by M. Hrasnica (2019) emphasizes the unique complexity of inspecting historical masonry after wars and natural disasters, where a significant portion of critical damage may initially remain hidden [7]. In turn, the results of the work by Nestor M. et al. (2022), using the example of reinforced concrete columns damaged by explosions, show how combined impacts lead to complex, non-linear damages poorly amenable to standard assessment methods [8]. This illustrates the principle of wholeness and unpredictability of

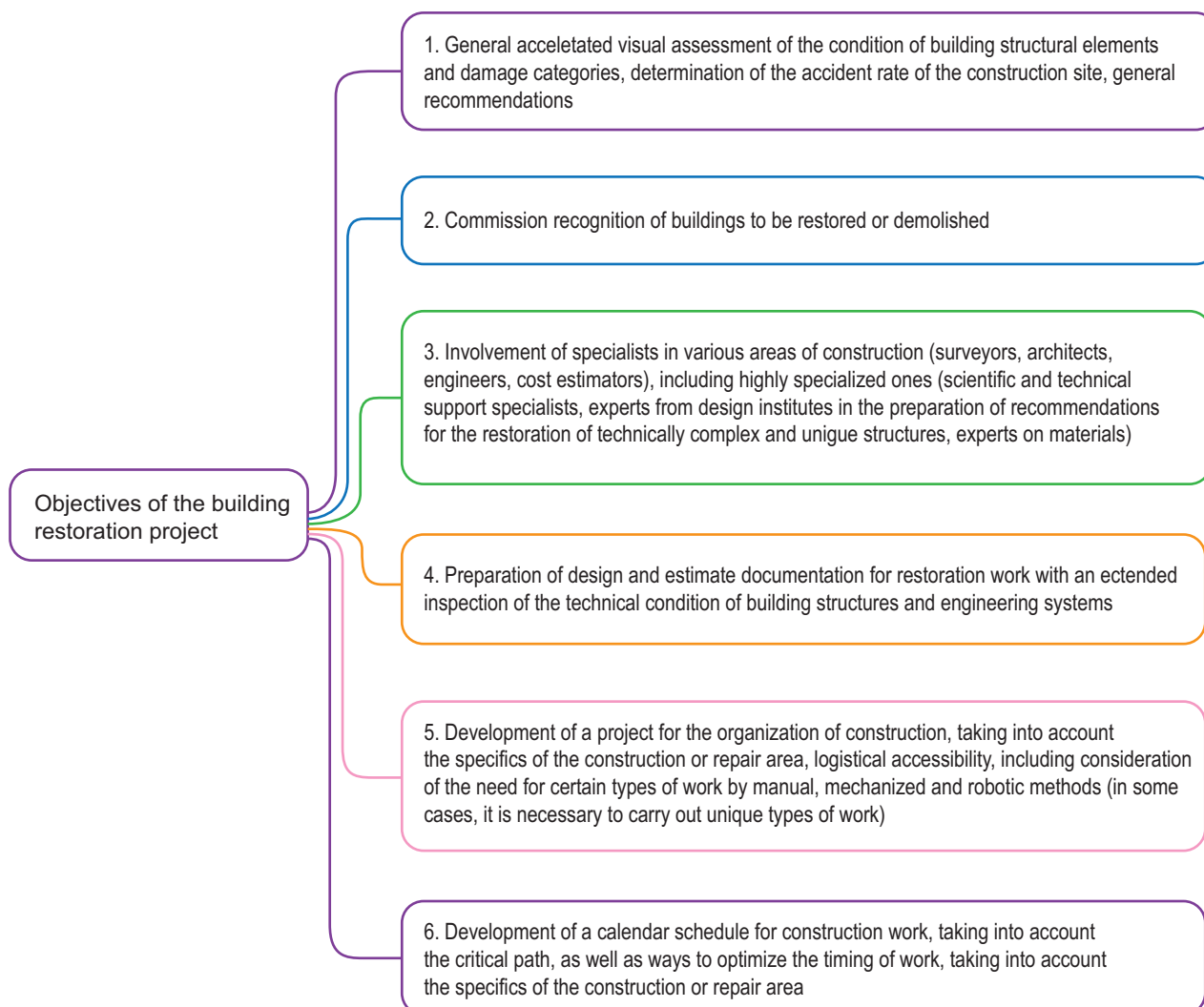


Fig. 4. Flowchart of main CRW (construction and restoration work) tasks

emergent systems, where the behavior of a damaged structure as a whole cannot be reduced to the simple sum of damages to its individual elements. This conclusion confirms the necessity for flexible design and the presence of a broad base of innovative solutions to adequately respond to the actual, and not just the projected, picture of destruction.

Speaking of the aspects of recovery planning and social adaptation, one cannot fail to mention the dissertation research by S. Kassouha (2020), which analyzes the application of post-war housing recovery methods from West Germany to contemporary Syria [9]. Its key finding is the impossibility of mechanically copying solutions without deep adaptation to local social, economic, and cultural conditions. This directly corresponds to the contextuality of the emergent effect and underscores the role of socio-technical interactions. Successful reconstruction leading to positive emergent results (as in the case of the village of Venzone) must consider the object not only as a physical structure but also as an element of a social system. Its restoration can become a catalyst for broader positive changes, taking into account the emergent historical specificities and identity of the CRW area [10, 11].

Thus, contemporary research in the field of damage assessment and recovery emphasizes three interconnected aspects critically important for realizing positive emergence in CRW:

- deep and iterative condition assessment, revealing hidden potential and risks;
- holistic engineering approach, accounting for non-linear interactions within the system of damages;
- adaptive socio-technical strategy, flexibly adjusting to varying situations.

The integration of these principles into the CRW organization system creates an environment where unforeseen circumstances are transformed from threats into opportunities for the evolutionary improvement of the object.

A post-collapse restoration project poses complex and unique tasks (Fig. 4).

These circumstances create an environment conducive to the emergent appearance of new architectural and engineering solutions. We can calculate the approximate probability of obtaining a positive result using mathematical models from statistics. By adapting statistical models to our case of CRW, we will introduce the necessary variables, calculate the probability of a positive emergent effect, and consider measures to compensate for such a non-primary factor as the presence of hidden defects not detected during the technical inspection.

► **CALCULATION OF THE PROBABILITY OF A POSITIVE EMERGENT EFFECT IN CONSTRUCTION USING THE EXAMPLE OF POST-COLLAPSE RECONSTRUCTION**

We will build a probabilistic-statistical model that accounts for key parameters influencing the outcome of reconstruction [12, 13].

1. Problem Statement

Let P_{+e} — be the desired probability of a positive emergent effect (PEE), i.e., the probability that the outcome of post-collapse reconstruction will lead to improved architectural, technical-economic, or functional characteristics of the building.

We proceed from a model of conditional probability considering independent variables (factors):

$$P_{+e} = P(E_1 \cap E_2 \cap E_3 \cap E_4), \tag{1}$$

where E_1 — presence of high competence of the design team in reconstruction projects;

E_2 — presence of an organizational knowledge base with a sufficient number of optimal and innovative technical solutions, enhancing the flexibility of applying design solutions;

E_3 — availability of sufficient resources (time, budget) for the timely implementation of changes in reconstruction projects;

E_4 — degree of elaboration of the architectural-functional improvement potential embedded in the project.

These events are assumed to be statistically independent for the sake of a first approximation (dependencies can be accounted for later if necessary).

2. Defining Probability Components

In Table 2, we adopt conditional probabilities (based on surveys and practice of design organizations, using a typical specimen of 50 reconstruction projects of various types of capital construction objects).

3. Calculation of Final Probability

Assuming factor independence:

$$P_{+e} = P(E_1) \cdot P(E_2) \cdot P(E_3) \cdot P(E_4), \tag{2}$$

where $P(E_i)$ — is the probability of each individual event.

Let's perform the calculation using the formula:

$$P_{+e} = 0.85 \cdot 0.6 \cdot 0.5 \cdot 0.7 = 0.1785.$$

4. Result Interpretation

The probability of a positive emergent effect in post-collapse reconstruction, according to this model, is ~17.85 %.

What this means:

- approximately in every fifth or sixth case, reconstruction yields improvement in architectural-functional characteristics due to emergent solutions;

Table 2. Adopted probabilities for each factor

Factor	Conditional event E_i	Probability estimation $P(E_i)$
Team Qualification	E_1	0.85 (85 %)
Flexibility of Design	E_2	0.6 (60 %)
Sufficiency of Budget/Time	E_3	0.5 (50 %)
Architectural Potential	E_4	0.7 (70 %)

- this is a relatively high probability, considering it involves deviation from planned, standard solutions under conditions of large-scale destruction.

5. Conclusion

The calculation shows that under favourable conditions, the probability of positive emergence reaches ~18 %, confirming the advisability of supporting design flexibility and allowing innovative approaches in post-collapse reconstruction conditions.

PROBABILITY OF A POSITIVE EMERGENT EFFECT (PEE) ACCOUNTING FOR THE RISK OF HIDDEN DEFECTS NOT IDENTIFIED DURING THE POST-COLLAPSE INSPECTION

We will introduce an additional random variable — the presence of defects in structures not accounted for by the inspection (hidden defects) (D) — and forecast its overall impact on the system.

Important clarification:

- this variable is non-normative in terms of assessment³;
- defects D are not a consequence of contractor errors;
- defects D are not related to poor workmanship but are caused by undetected (hidden) damages discovered only after the start of reconstruction.

Impact of undetected defects on the overall outcome:

- emergence of unplanned work volumes (additional reinforcement, dismantling, demolition, etc.);
- diversion of resources and time previously allocated for implementing innovative or architectural-functional improvements;
- shift in priorities: the design team may be forced to shift focus from optimization to threat mitigation;
- budget constraints, as the risk reserve budget may be fully utilized without replenishment;
- legal or contractual constraints: some decisions require recalculations, approvals, and deferred solutions.

General Extended Probability Model

We denote:

- P_{+e} : probability of a positive emergent effect;
- D : the event that the building has hidden defects not detected during the inspection;
- $\neg D$: there are no hidden defects or their presence has no significant impact on the result;
- $P(D)$: probability of the presence of undetected (hidden) defects;
- $P_{+e|D}$: probability of a positive effect given the presence of hidden defects;
- $P_{+e|\neg D}$: probability of a positive effect given full identification of the structure's condition during the inspection stage (the influence of hidden defects is not significant).

General formula:

$$P_{+e} = P(D) \cdot P_{+e|D} + (1 - P(D)) \cdot P_{+e|\neg D}. \tag{3}$$

Let us consider a case accounting for the previously considered model components (E_1, E_2, E_3, E_4).

³ GOST 31937-2024. Buildings and Structures. Rules for Surveying and Monitoring Technical Condition: effective date 01-05-2024. Official ed. Moscow, RIS, 2024; 64. URL: <https://docs.cntd.ru/document/1305691614> (rus.).

Then our formula takes the general form:

$$P_{+e} = P(E_1|D \cap E_2|D \cap E_3|D \cap E_4|D); \tag{4}$$

$$P_{+e} = P(E_1|D \cap E_2|D \cap E_3|D \cap E_4|D) = \\ = P(E_1|D) \cdot P(E_2|D) \cdot P(E_3|D) \cdot P(E_4|D), \tag{5}$$

where $E_1|D$ — presence of high competence of the design team in reconstruction projects where unaccounted-for hidden defects were identified during the installation process;

$E_2|D$ — presence of an organizational knowledge base with a sufficient number of optimal and innovative technical solutions, enhancing the flexibility of applying design solutions in case hidden structural damages are identified;

$E_3|D$ — availability of sufficient resources (time, budget) for timely implementation of changes in reconstruction projects where unaccounted-for hidden defects were identified during the installation process;

$E_4|D$ — degree of elaboration of the architectural-functional improvement potential embedded in the project.

Thus, the extended probability model:

$$P_{+e} = P(D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4|D) + \\ + P(\neg D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4| \neg D); \tag{6}$$

$$P_{+e} = P(D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4|D) + (1 - P(D)) \cdot P_{+e|\neg D}. \tag{7}$$

Parameter Estimation

Probability of hidden defects $P(D)$.

According to data from technical audits and engineering inspections of buildings after accidents, as well as conducted surveys of construction organizations, in 30–40 % of cases, not all significant defects can be detected at the inspection stage. Let us adopt an averaged probability value $P(D) = 0.35$.

Input parameters:

$P(D) = 0.35$ — probability of the presence of significant hidden defects;

$P(\neg D) = 1 - P(D) = 0.65$ — probability of the absence of hidden defects with significant influence.

Let us introduce a coefficient for reducing efficiency in the presence of defects — α_i , then:

- $P(E_i|\neg D)$ — effectiveness of the factor under normal conditions;
- $P(E_i|D) = \alpha_i \cdot P(E_i|\neg D)$, where $\alpha \in (0, 1)$ — is the efficiency reduction coefficient in the presence of defects (e.g., 0.6 means a 40 % drop).

Table 3. Data obtained from surveys conducted from 2021 to 2025

Factor	Mechanism of defect influence	Probability value α_i	Probability estimate $P(E_i \neg D)$	Probability estimate $P(E_i D)$, considering α_i
Team Qualification E_1	Efficiency remains unchanged, but the pace of work will decrease	0.75–0.85 (average 0.80)	0.85 (85 %)	0.79 (79 %)
Flexibility of Design E_2	The developed design solutions are subject to adjustments based on the actual situation	0.65–0.75 (average 0.70)	0.6 (60 %)	0.54 (54 %)
Sufficiency of Budget/Time E_3	A significant part of the budget/time is spent on correcting unforeseen design errors	0.55–0.65 (average 0.60)	0.5 (50 %)	0.43 (43 %)
Architectural Potential E_4	Forced adjustments to the project already during implementation may hinder the implementation of the architectural ideas originally laid down	0.85–0.95 (average 0.90)	0.7 (70 %)	0.68 (68 %)

Also, we consider the important condition that α_i is not a result of poor workmanship but a forced adaptation of the project to new conditions. Consequently:

- α_i values inevitably decrease even with high competence and a knowledge base;
- however, projects do not become failures; the overall emergent effect merely diminishes.

$$P(E_i) = \alpha_i \cdot P(E_i|\neg D) \cdot P(D) + P(E_i|\neg D) \cdot (1 - P(D)); \tag{8}$$

$$P(E_i) = P(E_i|\neg D) \cdot [\alpha_i \cdot P(D) + (1 - P(D))] = \\ = P(E_i|\neg D) \cdot [1 - P(D)(1 - \alpha_i)], \tag{9}$$

where $\alpha_i = 1$: unaccounted defects do not affect efficiency $\rightarrow P(E_i) = P(E_i|\neg D)$;

$\alpha_i < 1$: the smaller α_i , and the larger $P(D)$, the more the overall probability $P(E_i)$ decreases.

Table 3 presents data from surveys conducted among construction organizations and state institutions from 2021 to 2025, indicating averaged values of coefficient α_i and calculated $P(E_i|D)$ (probabilities considering defects).

Substituting the found values into our model for determining P_{+e} :

$$P_{+e} = P(D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4|D) + (1 - P(D)) \cdot P_{+e|\neg D} = \\ = 0.35 \cdot (0.79 \cdot 0.54 \cdot 0.43 \cdot 0.68) + 0.65 \cdot 0.1785 = \\ = 0.35 \cdot 0.1247 + 0.65 \cdot 0.1785 = 0.1597 (\sim 15.97 \%).$$

Result interpretation:

- accounting for the risk of hidden defects, the probability of a positive emergent effect decreases from ~17.85 to ~15.97 %;
- this is a reduction of ~2 percentage points (~10.5 % relative to the previous estimate);
- thus, timely and thorough inspection of structures before the start of reconstruction can significantly influence the probability of success.

BAYESIAN REVISION: $P(D|E)$

Suppose that after observing a positive emergent effect, we want to clarify the probability that hidden defects were nevertheless present:

$$P(D|E) = \frac{P(E|D) \cdot P(D)}{P(E)}. \tag{10}$$

Using the values obtained above from the calculation:
 $P(D) = 0.35$ — probability of the presence of hidden defects;
 $P(E|D) = P(E_1 \cap E_2 \cap E_3 \cap E_4|D) = 0.1247$ (calculated above);
 $P(E) = P_{+e} = 0.1597$ — total probability of a positive effect (calculated earlier by the total probability formula).
 Then we obtain:
$$\frac{P(D) \cdot P(E|D)}{P(E)} = \frac{0.35 \cdot 0.1247}{0.1597} = \frac{0.0436}{0.1597} = 0.2733 \text{ (~27.3\%).}$$

Conclusion: even with a positive effect, the probability that hidden defects were still present is about 27.3 %. This indicates that the system can adapt to shortcomings — emergence acts as a compensatory capability.

This implies:

- the possibility of achieving positive results even in the presence of unforeseen problems;
- but it also points to the necessity of a systems approach to design that accounts for potential uncertainty.

System interpretation (Systems Theory)

The model is based on 4 independent factors (E_1 – E_4), each influencing the system's readiness for adaptation:

- E_1 и E_2 — the cognitive-design loop (knowledge and competencies);
- E_3 — the resource loop (time, budget);
- E_4 — the architectural-functional potential (system reserve).

In terms of systems engineering:

1. The probability of PEE is the reliability of the system's functional reserve, realized under a certain configuration of factors.
2. The presence of hidden defects is a structural defect causing a potential "deviation from the norm".

The model's robustness is manifested in that even with the deterioration of one factor (e.g., the appearance of D), a positive outcome is still possible if strong compensating factors (E_1, E_2) are present.

The graph shows the dependence of the final probability of a positive emergent effect P_{+e} , accounting for hidden structural defects $P(D) = 0.35$, on the parameters:

- $P(E_1)$ — probability of having a competent design team;
- $P(E_2)$ — probability of flexibility of design solutions.

Key conclusions determined by the graph:

- with $P(D) = 0.35$, the effect of hidden defects reduces overall success but does not nullify it;
- the higher the values of E_1 and E_2 , the higher the final probability P_{+e} , but even with high values of E_1 and E_2 , the presence of hidden defects reduces the probability of a positive effect, albeit insignificantly;
- the presence of hidden defects lowers the overall probability level;
- the effect of improving E_1 and E_2 is more pronounced in the range of high values (from 0.6 and above), but with a low level of any factor, a sharp drop in P_{+e} is observed.

COMPENSATORY MEASURES TO REDUCE THE NEGATIVE IMPACT OF HIDDEN DEFECTS

To compensate for the negative impact of hidden defects ($P(D)$) on the probability of a positive emergent effect in post-collapse reconstruction projects, it is recommended to take measures to increase the resilience of the project system to uncertainty [14, 15]. Fig. 6 presents directions and practical measures.

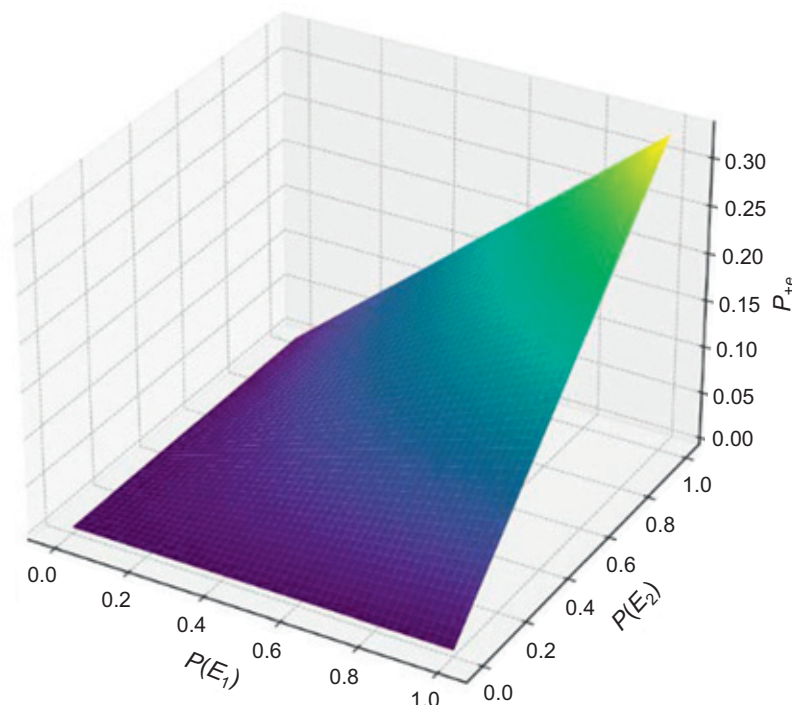


Fig. 5. Three-dimensional graph of result dependence on parameters E_1 and E_2 (dependence of P_{+e} on parameters E_1 and E_2 , taking into account hidden defects)

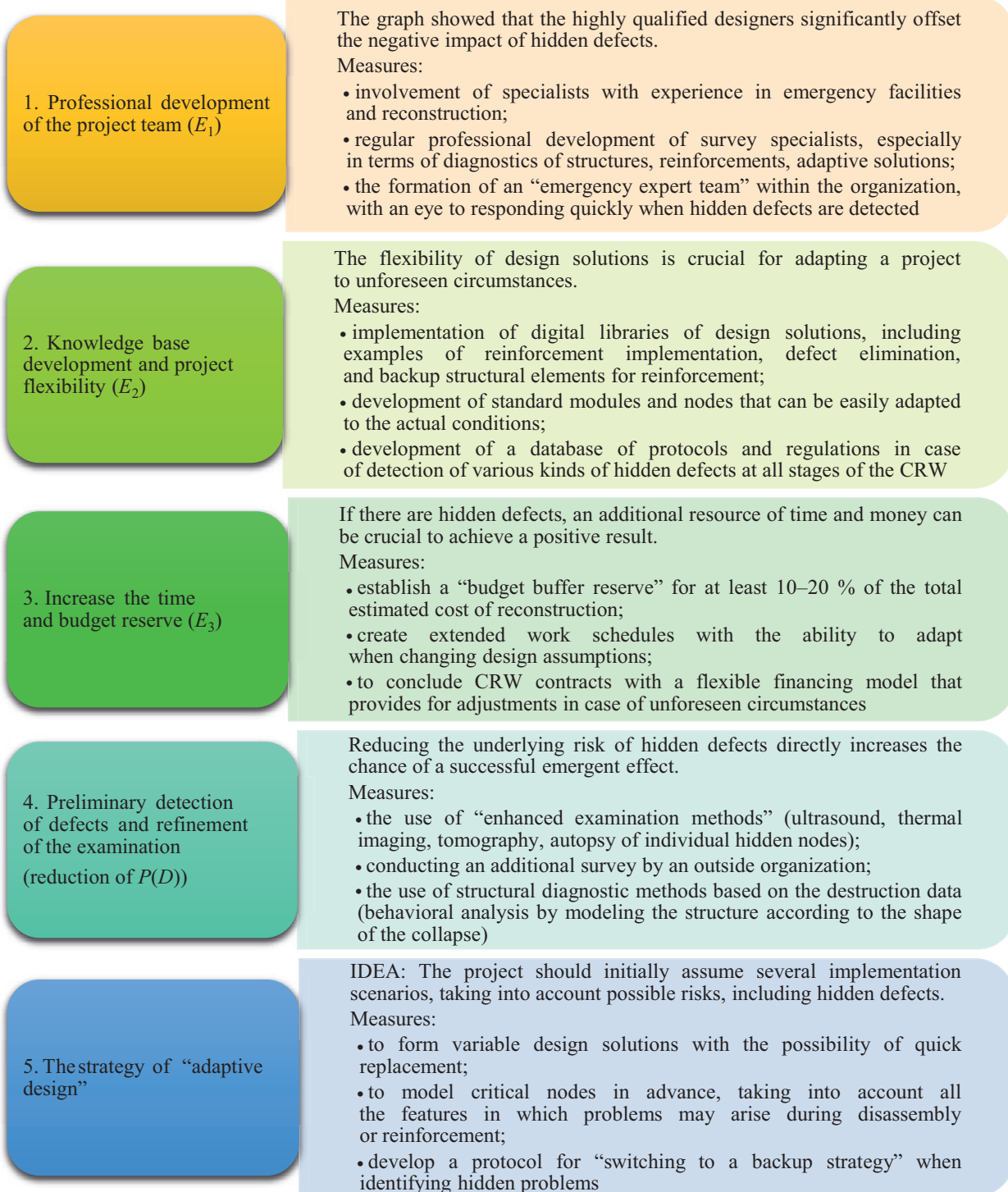


Fig. 6. Compensatory measures to reduce the negative impact of hidden defects

Conclusion from the statistical calculation

Even with $P(D) = 0.35$ (35 %), due to the professional level of the team and flexibility of solutions, the probability of a positive outcome can be doubled. Therefore, the main attention should be paid to:

- proactive uncertainty management;
- accumulation and transfer of knowledge;
- and the implementation of adaptive design as a mandatory stage in the reconstruction of emergency objects.

CONCLUSIONS

The process of conducting construction and restoration works on damaged buildings, despite the inherently negative fact of damage, can become a catalyst for such positive effects of synergistic construction systems as emergence. The analysis of a specific case showed that flexibility, collective intelligence, and adaptation to unforeseen circumstances can not only restore but also improve a building in a number of parameters. The proposed statistical

► model for forecasting the probability of obtaining a positive emergent effect, considering various types of damages not identified during inspection, allows for assessing the shortcomings of the construction-restoration system and increasing its effectiveness.

Thus, the positive emergent effect should be considered not as a side effect but as a potentially valuable objective in reconstruction and architectural design.

REFERENCES

1. Shirshchikov B.F., Akulich V.V. *Features of the development of organizational and technological solutions when performing construction and restoration work in emergency conditions*. Moscow, National Research University Moscow State University of Civil Engineering, 2015; 116. EDN VOCQWT. (rus.).
2. Belal A.A. *Features of urban restoration of the historical centers of cities in the SAR damaged during the war : dissertation for the degree of candidate of technical sciences*. Moscow, 2022; 136. EDN SCBJNW. (rus.).
3. Jeleński T. *Practices of Built Heritage Post-Disaster Reconstruction for Resilient Cities*. Buildings. 2018; 8(4):53. DOI: 10.3390/buildings8040053
4. Gusakova E.A. *Systems engineering of organizational and technological cycles of construction projects : dissertation for the degree of Doctor of Technical Sciences*. Moscow, 2004; 370. EDN NHZXVF. (rus.).
5. Gusakov A.A. *Systems Engineering in Construction*. Moscow, Stroyizdat, 1983; 440. URL: <https://search.rsl.ru/record/01001161266> (rus.).
6. Gusakova E.A., Pavlov A.S. *Fundamentals of Organization and Management in Construction : Textbook and Workshop for Secondary Vocational Education*. Moscow, Yurait, 2025; 615. URL: <https://>

rusneb.ru/catalog/000200_000018_RU_NLR_BIBL_A_011289934 (rus.).

7. Hrasnica M. *Damage assessment for masonry and historic buildings in Bosnia and Herzegovina. Damage Assessment and Reconstruction After War or Natural Disaster*. 2019; 333-356. DOI: 10.1007/978-90-481-2386-5_13
8. Mejía N., Peralta R., Tapia R., Durán R., Sarango A. *Damage assessment of RC columns under the combined effects of contact explosion and axial loads by experimental and numerical investigations*. Engineering Structures. 2022; 254:113776. DOI: 10.1016/j.engstruct.2021.113776. EDN SWYXTO.
9. Kassouha S. *Transferring experiences of post-war west Germany in social housing to reconstruction strategies after the war in Syria : dissertation*. Stuttgart, Germany, 2020; 482. DOI: 10.18419/opus-10826
10. Ho J.T.s.W. *Emergent place-identity: place activation through the architectural restoration of a small Hakka household in the Hong Kong countryside*. Built Heritage. 2024; 8(1):7. DOI: 10.1186/s43238-024-00117-4. EDN WVDAXG.
11. Bunin A.V., Savarenskaya T.F. *History of urban planning art : in 2 volumes. Vol. 2. Urban planning of the twentieth century in the countries of the capitalist world*. Moscow, Stroyizdat, 1979; 411. URL: <https://search.rsl.ru/record/01007592487> (rus.).
12. Semenov V.A. *Probability Theory and Mathematical Statistics : a Textbook for Bachelors and Specialists*. St. Petersburg, Piter, 2013; 192. URL: <https://search.rsl.ru/record/01006510355> (rus.).
13. Kremer N.Sh. *Probability Theory and Mathematical Statistics*. Moscow, Unity-Dana, 2003; 573. EDN QJMCDH. (rus.).
14. Maaruf A., Oleinik P.P. *Measures to prepare the territories damaged by the war for the restoration of the housing stock*. Engineering Journal of Don. 2023; 10(106):330-342. EDN PRIUPO. (rus.).
15. Borisov A.M., Vertakova Yu.V. *Strategic management of organizational viability based on the application of a balanced scorecard system*. Moscow, INFRA-M, 2019; 238.

Положительный эффект эмерджентности в системе строительно-восстановительных работ после обрушения зданий

Рассматривается феномен позитивной эмерджентности в синергетической системе строительно-восстановительных работ (СВР), возникающей после обрушения зданий вследствие значительных природных или техногенных воздействий. Эмерджентность понимается как появление качественно новых, непредусмотренных изначально свойств системы, ведущих к улучшению объекта. На примере восстановления итальянской деревни Венцоне после землетрясения 1976 г. показано, как катастрофа может стать катализатором эволюции, приводящей к росту архитектурной выразительности, функциональности, туристической привлекательности и социально-экономической значимости восстанавливаемого объекта. Отдельное внимание уделено социотехническим взаимодействиям, роли интуитивных и креативных решений, и гибкости проектных команд, позволивших использовать катастрофу как возможность для эволюции архитектурного объекта в условиях неопределенности. На основе анализа реальных случаев и теоретической базы предлагается вероятностно-статистическая модель для прогнозирования положительного эффекта эмерджентности (ПЭЭ). Модель учитывает ключевые факторы: компетентность команды, гибкость проектных решений, достаточность ресурсов и архитектурный потенциал. Расчет показывает, что при благоприятных условиях вероятность ПЭЭ достигает больше 17 %. При этом вводится важный корректирующий фактор — риск наличия

скрытых дефектов, не выявленных при обследовании. Учет этого фактора в модели вносит важные уточнения и снижает вероятность ПЭЭ, тем самым подчеркивая критическую важность тщательного предпроектного анализа. Практическая значимость работы заключается в обосновании ценности адаптивного проектирования и управления неопределенностью для реализации эмерджентного потенциала в строительно-восстановительных проектах. Предложенная модель и выводы служат основой для разработки компенсирующих мероприятий, направленных на минимизацию негативного влияния непредвиденных факторов. Заключительно делается вывод, что положительный эмерджентный эффект следует рассматривать как целевой, а не побочный элемент реконструкции, способный превратить процесс ликвидации повреждений в возможность системного улучшения восстанавливаемого объекта по широкому спектру параметров — от технико-экономических до социокультурных.

Ключевые слова: эмерджентность, строительно-восстановительные работы, синергетика, вероятностное прогнозирование, гибкость проектных решений, скрытые дефекты

СПИСОК ИСТОЧНИКОВ

1. Ширшиков Б.Ф., Акулич В.В. *Особенности разработки организационно-технологических решений при выполнении строительно-восстановительных работ в чрезвычайных условиях : монография*. М. : НИУ МГСУ, 2015. 116 с. EDN VOCQWT.
2. Белал А.А. *Особенности градостроительного восстановления исторических центров городов САР, пострадавших в ходе войны : дис. ... канд. техн. наук. М., 2022. 136 с. EDN SCBJNW.*

3. Jeleński T. *Practices of Built Heritage Post-Disaster Reconstruction for Resilient Cities // Buildings*. 2018. No. 8 (4). P. 53. DOI: 10.3390/buildings8040053
4. Гусакова Е.А. Системотехника организационно-технологических циклов объектов строительства : дис. ... д-ра техн. наук. М., 2004. 370 с. EDN NHZXVF.
5. Гусаков А.А. Системотехника строительства. М. : Стройиздат, 1983. 440 с. URL: <https://search.rsl.ru/ru/record/01001161266>
6. Гусакова Е.А., Павлов А.С. Основы организации и управления в строительстве : уч. и практикум для среднего профессионального образования. М. : Юрайт, 2025. 615 с. URL: https://rusneb.ru/catalog/000200_000018_RU_NLR_BIBL_A_011289934
7. Hrasnica M. *Damage assessment for masonry and historic buildings in Bosnia and Herzegovina // Damage Assessment and Reconstruction After War or Natural Disaster*. 2019. Pp. 333–356. DOI: 10.1007/978-90-481-2386-5_13
8. Mejía N., Peralta R., Tapia R., Durán R., Sarango A. *Damage assessment of RC columns under the combined effects of contact explosion and axial loads by experimental and numerical investigations // Engineering Structures*. 2022. No. 254. P. 113776. DOI: 10.1016/j.engstruct.2021.113776. EDN SWYXTO.
9. Kassouha S. *Transferring experiences of post-war west Germany in social housing to reconstruction strategies after the war in Syria : dissertation*. Stuttgart, Germany, 2020. P. 482. DOI: 10.18419/opus-10826
10. Ho J.Ts.W. *Emergent place-identity: place activation through the architectural restoration of a small Hakka household in the Hong Kong countryside // Built Heritage*. 2024. No. 8 (1). P. 7. DOI: 10.1186/s43238-024-00117-4. EDN WV DAXG.
11. Бунин А.В., Саваренская Т.Ф. *История градостроительного искусства : в 2-х т. Т. 2. Градостроительство XX в. в странах капиталистического мира*. М. : Стройиздат, 1979. 411 с. URL: <https://search.rsl.ru/ru/record/01007592487>
12. Семёнов В.А. *Теория вероятностей и математическая статистика : уч. пос. для бакалавров и специалистов*. СПб. : Питер, 2013. 192 с. URL: <https://search.rsl.ru/ru/record/01006510355>

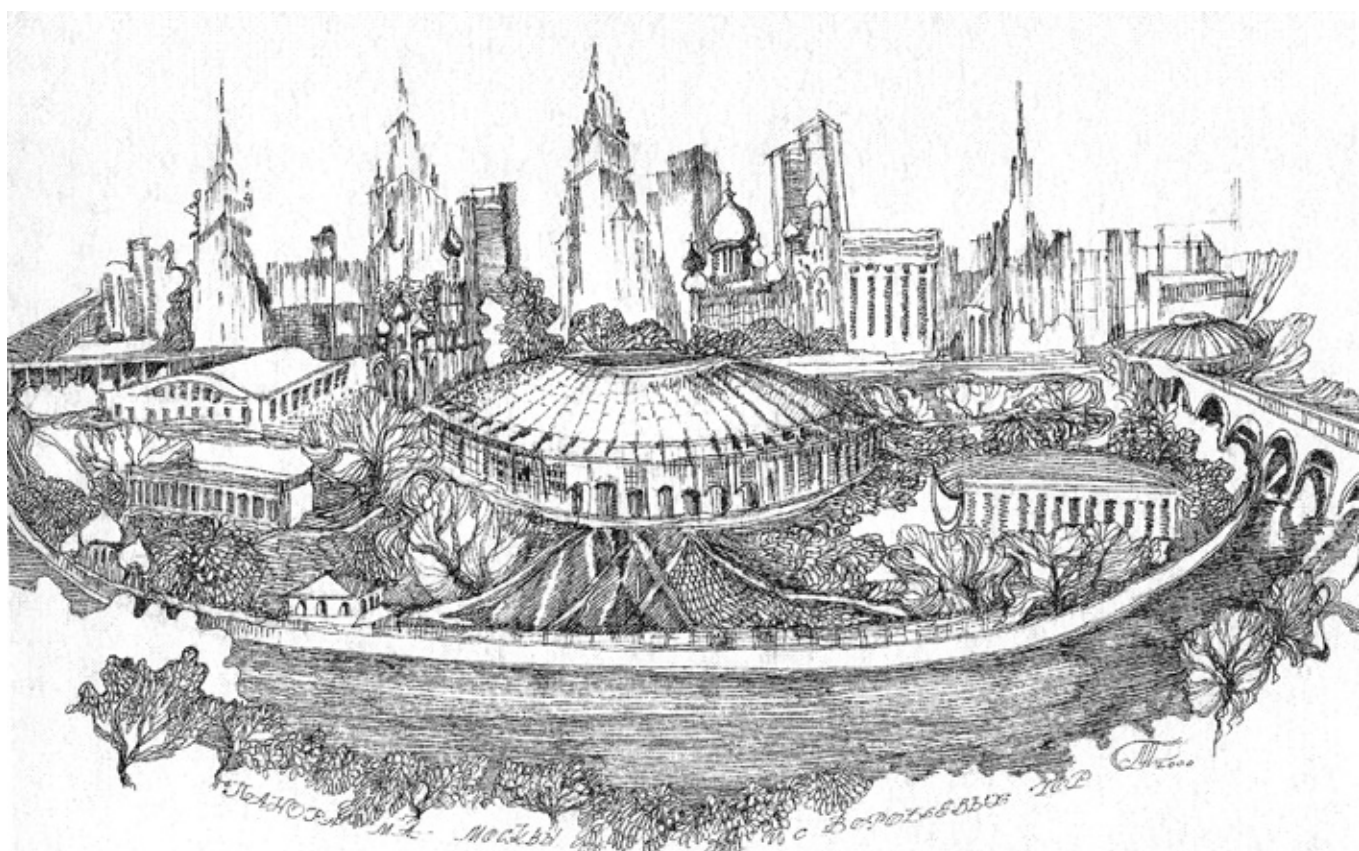
13. Кремер Н.Ш. *Теория вероятности и математическая статистика* М. : Юнити-Дана, 2003. 573 с. EDN QJMCDH.
14. Мааруф А.Г., Олейник П.П. Мероприятия по подготовке территорий, поврежденных войной, к восстановлению жилищного фонда // *Инженерный вестник Дона*. 2023. № 10 (106). С. 330–342. EDN PRIUPO.
15. Борисов А.М., Вертакова Ю.В. *Стратегическое управление жизнеспособностью организации на основе применения системы сбалансированных показателей : монография* М. : ИНФРА-М, 2019. 238 с.

Об авторах: **Мищенко Валерий Яковлевич** — д-р техн. наук, профессор кафедры «Организация строительства и управление недвижимостью»; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 386458, Scopus AuthorID: 57195990417, WoS ResearcherID: AAB-9505-2019, ORCID: 0000-0003-2385-5426; oseun@yandex.ru;

Чечин Кирилл Александрович — аспирант кафедры «Организация строительства и управление недвижимостью»; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; SPIN-код: 9428-9349; chech.kirill@yandex.ru.

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