INNOVATIONS IN THE PROTECTION OF THE POPULATION DURING DISASTERS AND CRISES

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Abstract

This article explores the role of innovations in population protection during disasters and crises. It analyzes new technologies, methods, and organizational solutions that enhance the effectiveness of emergency management. Emphasis is placed on the application of digital platforms, early warning systems, automated monitoring and analysis tools, as well as the use of artificial intelligence for predictive purposes. Innovative approaches to training and preparing the population for threat response are also examined. International best practices and perspectives for national adaptation are presented. The findings highlight the importance of innovation as a key factor for strengthening societal resilience in the face of future disasters and crises.

Keywords: *Innovative Technologies; Population Protection; Disasters; Crises; Early Warning; Resilience; Risk Management.*

INTRODUCTION

In an environment of global uncertainty and the increasing frequency of disasters and crises, traditional methods of population protection are proving insufficient. The development of society requires an innovative and anticipatory approach that integrates technological advancement, inter-institutional cooperation, and the active participation of citizens [1].

According to the OECD (2022), innovation is an integral part of sustainable risk management – it accelerates response, improves communication, and enables systems to adapt to unpredictable threats [2].

Population protection is no longer an isolated activity of individual institutions but a networked process that incorporates information technologies, social media, volunteer formations, the private sector, and the scientific community.

EXPOSITION

1. Conceptual Foundations of Innovation in Population Protection

1.1. Technological and Digital Innovations

Digitalization is a key driver of modern disaster management. It enables:

- the integration of data from various sources (meteorological, geospatial, and social);
- the establishment of multi-hazard early warning systems (MHEWS);
- the creation of operational centers with access to real-time information.

An example of such practice is the European COPERNICUS Emergency Management Service (EMS), which provides satellite imagery and analyses for damage assessment and operational planning [3].

In the Bulgarian context, similar potential is demonstrated by the National Early Warning and Notification System (NEWS) and the digitalized population protection plans maintained by local authorities.

1.2. Organizational and Communication Innovations

Modern crises are complex and often require a simultaneous response from multiple institutions. This necessitates the development of integrated systems for coordination and information exchange.

One of the most effective organizational innovations is the implementation of a network-based management model, in which institutions operate not hierarchically but as equal nodes within a communication network.

This approach ensures synergy and interconnectivity, leading to faster decision-making, better situational awareness, and optimized use of resources.

It transforms crisis management from a vertical, command-centered process into a horizontal, collaborative system, where public institutions, local authorities, private operators, and civil society interact dynamically to achieve common goals of population safety and resilience. This relationship can be expressed as follows:

$$C_s = f(K, T, I), \qquad (1)$$

where:

C_S – coordination synergy – the overall effectiveness of inter-institutional interaction;

K – knowledge exchange between institutions and stakeholders;

T – technological connectivity – the degree of interoperability of communication and information systems;

I – institutional integration, meaning the extent to which organizations collaborate through joint protocols, agreements, and coordinated actions.

An increase in C_S signifies improved coordination efficiency, resulting in faster and more accurate responses.

The indicators are determined according to the principles presented in Table 1.

Table 1. Criteria for coordination synergy

Parameter	Method of assessment	Range	Average values
K – knowledge exchange	Number of joint trainings, exercises, seminars, and information-sharing protocols, normalized as a percentage of those planned.	0-1	0,7 – when 70% of trainings are realized
T – technological connectivity	Degree of interoperability between information systems and operational platforms (based on checklist or expert evaluation).	0-1	0,8 – when two-way data exchange exists between key institutions
I – institutional integration	Ratio of signed cooperation agreements to those planned.	0-1	0,6 – when 60% of agreements are formalized

When C_S increases, the system achieves higher stability, speed, and accuracy of response.

Example:

$$C_s = (K + T + I)/3 = (0{,}7 + 0{,}8 + 0{,}6)/3 = 0{,}7$$

Therefore, coordination is good (above a threshold value of 0,6, effective connectivity is assumed to be functioning).

This model is consistent with practices of the WMO (2023) and UNDRR (2020) within the *Early Warnings for All* initiative, emphasizing *shared situational awareness* [4].

1.3. Social and Educational Innovations

Training and citizen participation are essential for building resilience.

Innovative approaches include:

- virtual simulations and VR-based training for responders and citizens;
- online volunteer platforms for registration and coordination of community-based response teams;
- educational gamification tools for youth, promoting behavioral readiness during fires, earthquakes, or floods.

The effectiveness of such approaches can be expressed through the conceptual relationship:

$$R_p = U_c \times (E_o + P_a), \tag{2}$$

where:
R_P – population readiness;
U_C – community participation;
E_O – effectiveness of education;
P_a – practical engagement through exercises and awareness campaigns.

Higher values of R_P correspond to greater social resilience and reduced dependence on central intervention.

2. Models of Resilience and Adaptability

Modern resilience theory views systems as adaptive and dynamic. The resilience of a population protection system depends not only on available resources but also on its capacity for self-organization and learning.

It can be conceptually represented as:

$$R_s = \frac{A+F+L}{3}, \tag{3}$$

where:
R_S – integrated resilience;
A – adaptability;
F – functional flexibility;
L – learning capacity.

Higher values of A, F, and Lindicate more effective crisis management under uncertainty. This approach aligns with the principles of OECD (2022) and MSB (2021), which emphasize that resilience arises from the balance between technological preparedness and social cohesion [2], [5].

3. International Best Practices

- Japan: operates the J-Alert system for nationwide broadcasting via radio, television, and mobile networks, achieving reaction times under 10 seconds;
- The Netherlands: employs digital twins for real-time simulation of dike performance during floods;
- Sweden (MSB, 2021): conducts national awareness campaigns promoting individual preparedness for crises [5].
- United States (FEMA, 2022): has developed integrated communication platforms enabling rapid resource mobilization and inter-agency coordination [6].

These examples illustrate that innovative management and communication systems reduce response time, enhance coordination, and save lives.

4. Proposed Conceptual Relationships

Functional Efficiency of Innovation:

$$E_f = \frac{I_t \cdot C_S}{R_d}, \qquad (4)$$

where:
E_f – functional efficiency;
I_t – technological intensity;
C_S – coordination synergy;
R_d – resource dependence.

Lower R_d (i.e., greater self-sufficiency) and higher I_t and C_S yield improved operational performance.

Integrated Readiness Index:

$$G_i = \frac{T_r + O_c + P_r}{3}, \qquad (5)$$

where:
G_i – integrated readiness;
T_r – technical readiness;
O_C – organizational coordination;
P_r – психологическа готовност на населението.

Values of G_i>0,7 indicate effective integration between technological capacity and societal resilience.

Conclusion

Innovation in population protection extends beyond technological modernization – it encompasses a comprehensive transformation of risk governance.

An effective disaster protection system must be:

Integrated, through shared information and interoperable operational platforms;
Adaptive, capable of responding to unpredictable threats;
Socially resilient, engaging citizens and communities in proactive preparedness.

The synergy between technological, organizational, and educational innovations enhances response efficiency, reduces losses, and strengthens overall resilience.

As OECD (2022) notes, innovation is not optional but a necessity for managing future risks in an interconnected world [2].

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