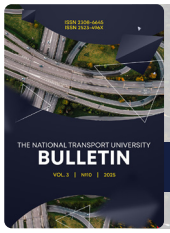

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Implementation of world experience in constructing civil defence shelters

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Abstract. The intensification of contemporary military threats in Ukraine has necessitated a reassessment of approaches to civil protection and the integration of protective shelters into residential and civil infrastructure. The study aimed to analyse Ukrainian legislation alongside selected international practices in order to identify effective models for incorporating protective spaces into buildings and to substantiate directions for expanding the classification of protective structures. The methodological framework was based on a comprehensive analysis of national regulatory documents, a comparative evaluation of international experience, and the generalisation and systematisation of best practices. Particular attention was given to the legislative and technical approaches implemented in Israel and Singapore, especially regarding the integration of shelters into buildings, rapid accessibility, and functional efficiency. The research also considered economic feasibility and the practical aspects of implementing such solutions within existing and newly constructed facilities. The findings demonstrated that international practice consistently emphasised the critical importance of minimising the time required for citizens to access shelters, which was achieved through the integration of protected spaces directly into residential and industrial buildings or through the deployment of modular shelter systems. The analysed cases revealed that such approaches ensured a higher level of population safety, particularly under conditions of frequent and unpredictable threats. It was established that both Israel and Singapore had successfully embedded these solutions within their legislative frameworks, supported by clearly defined technical standards. The study substantiated the feasibility of gradually introducing integrated and modular protective structures in Ukraine, both in the process of post-war reconstruction and in new construction projects. The practical significance of the research lay in the formulation of recommendations for adapting Ukrainian legislation and improving the accessibility, efficiency, and resilience of civil protection infrastructure

Keywords: protected space; dual-purpose structures; urban resilience; subsurface spaces; Mamads

Introduction

Modern security challenges have necessitated the implementation of new protective solutions alongside the modernisation of existing civil defence infrastructure. In Ukraine, this process has gained renewed momentum following the introduction of updated state standards governing the construction of protective structures. These regulatory changes have established new directions for development; however, they have also revealed significant limitations, as not all solutions formally covered by existing standards provide an adequate level of real

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protection under contemporary conditions. Therefore, it is essential to consider and adapt the experience of countries that have long operated under conditions of persistent military or terrorist threats, particularly Israel and Singapore, as noted by S.M. Anas *et al.* (2023). In the current conditions faced by Ukraine, characterised by ongoing warfare and continuous shelling involving various types of weaponry, the time required to reach a shelter has become a critical factor in ensuring civilian safety. The effectiveness of civil protection systems is increasingly determined not only by the structural reliability of shelters but also by their accessibility and proximity to users. The development and implementation of new types of temporary protective structures have enabled rapid access to safe spaces for the population. At the same time, A.I. Almulhim (2025) demonstrated that in high-density urban environments, effective civil protection is based on the integration of shelters into existing infrastructure, particularly transport nodes and underground spaces. It was emphasised that minimising the time required to access shelters directly correlates with increased survival rates. The main regulatory document in Ukraine governing the construction of shelters and bomb shelters is DBN V.2.2-5:2023 (2023). Compared with previous editions, this standard introduced a new category of shelters – rapidly deployable protective structures – alongside existing types such as anti-radiation shelters and the simplest shelters, with specific requirements defined for each category. All of these structures belong to collective protection facilities. However, the continuously evolving nature of military threats, including the changing characteristics of air attacks, necessitates a fundamental rethinking of existing approaches to shelter design and deployment.

Initial steps towards implementing new approaches have already been observed. The first modular underground shelter, constructed by the State Agency for Restoration and Infrastructure Development, was installed in the Kyiv region, indicating the beginning of the state-level introduction of rapidly deployable shelter solutions capable of providing a basic level of protection for the population (Ministry for Communities and Territories Development of Ukraine, n.d.). These structures are characterised by short installation times and immediate operational readiness. Rapidly deployable modular protective structures represent one of the most promising approaches to enhancing civil protection, although their practical implementation remains limited. Their requirements are defined in DSTU 9195:2022 (2022), which regulates their design and operation. A further promising direction involves the integration of protective spaces into transport and urban infrastructure, including tunnels, service galleries, and subsurface areas beneath road structures. This approach enables the expansion of shelter capacity within existing urban environments without the need for extensive new construction. The operational suitability of protective structures is assessed in accordance with DSTU 9329:2025 (2025), which establishes procedures for verifying the protective properties of enclosing structures prior to commissioning. In addition, with the development of modular shelters, national methodologies for testing such structures for blast resistance have begun to emerge, drawing on international experience, including that of the Singapore Civil Defence Force (n.d.). As emphasised by S. Surkes (2025) and Y. Wu *et al.* (2025), effective national protection systems rely not only on dedicated shelters but also on the utilisation of existing housing stock, including household shelters, residential shelters, protected rooms, and communal protected spaces. In parallel, the study by M. Zohourian *et al.* (2025) examined modular construction as an innovative approach within the construction industry, highlighting its advantages over traditional methods. The results indicated that modular construction could reduce construction time by up to 50%, lower costs by approximately 20%, and decrease material waste by up to 83%. At the same time, several limitations were identified, including transportation complexity, limited design flexibility, and high initial costs. These findings are particularly relevant for the implementation of modular shelters in emergency conditions. Despite these developments, Ukraine currently lacks clearly defined technical requirements for so-called "protected spaces" integrated into buildings, which prevents their formal recognition as a distinct category of protective structures. Nevertheless, initial steps have already been taken at the regional level, where local authorities have developed recommendations concerning underground shelter premises, protected spaces within residential and office buildings, and requirements for engineering systems and spatial planning. Therefore, addressing this problem requires the development of a modern approach to shelter design based on the concept of integrated protected spaces ("safe spaces"), capable of providing effective protection under contemporary military conditions. The purpose of this article was to investigate best practices in civil and residential construction regarding the availability and accessibility of protective structures and to identify potential directions for adapting Ukrainian civil engineering legislation in order to introduce new types of shelters that correspond to current threats and post-war recovery needs.

Materials and Methods

The study was theoretical and analytical in nature and was conducted within an interdisciplinary framework at the intersection of civil engineering, urban planning, and civil protection systems. The object of the research was the process of formation and development of civil protection shelter systems under contemporary military threats. The subject of the research comprised the principles of integrating protective spaces into residential, public, and engineering infrastructure, as well as the regulatory and technical mechanisms for their implementation. The theoretical and regulatory framework of the study was based on current Ukrainian building codes and standards (in particular, DBN V.2.2-5:2023 (2023), DSTU 9195:2022 (2022) and DSTU 9329:2025 (2025)), international regulatory acts and technical standards (including civil protection

regulations of Israel and Singapore), as well as contemporary scholarly publications addressing shelter design, modular construction, and urban resilience. A set of interrelated scientific approaches was employed in the study. The systems approach enabled protective structures to be considered as elements of a unified civil protection infrastructure. The comparative approach was used to analyse international experience and to identify differences in design approaches and regulatory frameworks for shelters. The institutional approach provided an assessment of the role of state regulation in shaping an effective system for population protection. The principal research methods included the analysis of regulatory and legal documents governing the design and operation of protective structures; a comparative analysis of international experience (Israel and Singapore); the method of generalisation for systematising identified practices; and the method of scientific interpretation to formulate conclusions regarding their potential adaptation in Ukraine. The selection of countries for comparative analysis was determined by their practical experience in operating civil protection systems under constant or potential threats. Israel was selected as an example of a state with extensive experience in integrating protected spaces into residential development and with stringent regulatory frameworks. Singapore was considered an example of a highly developed urban system in which shelters were integrated into urban infrastructure and regulated at the legislative level. Such a selection made it possible to establish a representative basis for comparison and to identify directions for adapting international experience to the Ukrainian context.

Results and Discussion

Considering the experience of Israel, which has built a new construction concept based on a set of principles for creating so-called "residential protected rooms", the legislation and technical standards of this country provided for the creation of specific types of reinforced rooms. According to State comptroller of Israel (2024), the main state principles could be divided into 4 points:

Principle 1. Everyone needs protection. Wherever a person is, they must have access to any shelter. For example: mobile shelters at bus stops, underground shopping centres, subway stations, hotel parking lots, educational centres, gyms – anything that can be considered as a shelter should be an open refuge 24/7 for everyone, supplied with water, lighting, and ventilation. A situation like in Ukraine, where public buildings close during an alarm, public transport stops, and people are turned out onto the street, is unacceptable. On the contrary, everything that can provide protection must be open. And everyone must know where to go in case of danger.

Principle 2. Capsule security. In Israel, in addition to conventional bomb shelters, a numerous of other types of shelters are used. Mamad – (an abbreviation for merhav mugan dirati – "protected apartment space"). This kind of room with massive, usually 30-centimeter, reinforced concrete walls, thickened ceilings, metal airtight doors that withstand blast waves, and shutters made of two-centimetre steel sheets. Mamads began to be created so that people would not have to run outside to reach a bomb shelter but could literally go into an adjacent protected room. The capsule must have its own ventilation with an air filter for chemical protection and special doors.

Mamak – a fortified room in public buildings, located on each floor where people are present. In office buildings, these can serve as internal conference rooms. In apartment buildings, they are created within the volume of the staircase and are located on each floor for use by several families. The size of a Mamak was calculated based on the number of people on the floor. Such fortified rooms were built one above the other to increase structural stability. They could protect occupants from missile and shell fragments, as well as from chemical threats and earthquakes. Without their presence, city authorities would not grant a building permit or commission the building. The construction of buildings with protected spaces began only after 1993. For older buildings, the government launched a renovation programme called TAMA-38. The aim was to reinforce buildings that did not have Mamads. With the consent of 75% of the building's residents, a developer could add Mamads, as well as two or three additional floors of apartments for sale. In some cases, developers also added a lift and reinforced the building's façade. Since 1992, all new residential buildings in Israel have been required to include a reinforced room for protection during rocket and missile attacks. A reinforced room in a house or apartment had to measure at least nine square metres (96 square feet) (Zatulsky, 2023).

Figure 1. Fortified room Mamad during and after construction

Source: A. Zatulsky (2023)

Figure 1 depicts the process of modular construction of Mamad fortified structures – from the manufacture and

installation of reinforced concrete blocks to their integration into residential developments. It visually demonstrates the principle of vertical stacking of these modules and their standardisation as components of a civil defence system. Despite the fact that such shelters did not provide a one hundred per cent guarantee of safety, they significantly reduced the time required to reach cover and, consequently, decreased the likelihood of injury from building debris or shrapnel. Temporary or mobile fortification structures were also used. Migunit was a cuboid, box-shaped, dome-shaped, or tent-shaped shelter made of high-quality reinforced concrete and placed in open areas. It had two open exits, allowing people to enter quickly, wait out an attack, and then exit safely. These structures were located at bus stops, along highways, and on streets, enabling people to take cover during shelling while waiting for transport. Children's centres, playgrounds, and hospitals were equipped with additional arched canopies over roofs to provide protected spaces for children's activities, as well as concrete play tunnels painted and shaped like caterpillars for aesthetic appeal. All of this created additional protection and allowed for rapid shelter in the event of sudden danger (State comptroller of Israel, 2024).

Principle 3. Continuous review of building standards towards strengthening. The certification and attestation of new or reconstructed buildings mandatory involves the Ministry of Home Front. This ministry developing requirements, without the fulfilment of which, a developer cannot approve a project or commission a building. The Ministry of Home Front checks the implementation of requirements regarding the shelters compliance to national and local legislation. Each city, regularly, checks how well the infrastructure meets requirements, how quickly people can use it and reach a shelter. Ensuring security is not just a code of requirements for building supplies or work methods. It is a complex set of measures whose ultimate goal is to create a safe environment (Israel's bomb shelters…, 2023; de Yong *et al.*, 2024).

Principle 4. Architectural planning was based on the concept of the "wind rose of war". In border areas, consideration was given to how people could safely reach their homes after entering the yard and parking their vehicles. The building complex was designed taking into account the "wind rose of war", meaning that walls were reinforced and positioned depending on the direction from which a threat might arise. An illustrative example was a school in the city of Sderot, located 4 km from the Gaza Strip. This distance corresponded to approximately a 3-second rocket flight. Therefore, the building was constructed as a complete bomb shelter, with windows oriented away from the Gaza Strip. Another example was a hospital located 25 km from the border, where almost all departments, including maternity wards and facilities for people with disabilities, formed a single large bunker. At the sound of sirens, it was sufficient to close the shutters, after which up to 60% of the hospital became encapsulated; even surgical operations did not stop. During periods of intense shelling, protective doors were also used. Buildings included a fortified room on each floor, and the overall structure was designed so that external walls or specific parts of the building absorbed the main impact, thereby protecting the internal "capsule" where people were located, while only the blast wave affected the capsule itself (Shadan *et al.*, 2024).

Despite the fact that Singapore was a country that had not participated in any armed conflict and had not conducted hostilities on its territory, after the Second World War it became concerned with how to protect its population from potential threats. Singaporean legislation established several types of shelters mandatory for urban planning: household shelters, storey shelters, public shelters, and improvised shelters (Singapore Civil Defence Force, n.d.). People could use any of the more than 595 public shelters listed in the List of Civil Defence Public Shelters (2025) simply by reaching the nearest one. Civil buildings, such as metro stations, schools, and office centres, were designed to be used as improvised shelters if necessary. In particular, in underground metro stations, blast doors separated the underground level from the concourse level, thereby protecting people inside from potential external explosions. All metro stations were equipped with generators and their own air filtration systems, ensuring a continuous supply of electricity, drinking water, and clean air. Since 1997, it became mandatory for every apartment in a residential building to include a built-in shelter. Located one above the other, these individual household shelters were constructed from thick reinforced concrete and were strong enough to withstand bombardment. However, in the event of a direct hit and the collapse of the entire structure, it was unlikely that only a vertical column of fortified rooms would remain intact. In accordance with the Civil Defence Shelter Act 1997 (2020), the primary purpose of such shelters was to protect residents from fragments during explosions, as flying glass, concrete debris, and shrapnel typically caused most injuries. It should be noted that in the aforementioned countries, technical requirements for such shelters were strictly regulated and mandatory.

Ukraine was undergoing processes similar to those experienced by Israel 50 years earlier: with still weak protection, but a strong understanding of the need to adapt everyday life to the conditions of war. Over nearly three years of war, Ukrainian infrastructure, business processes, and society had already begun this transformation (Reznikova & Korniievskyi, 2024). The main regulatory document in Ukraine governing the construction of shelters and bomb shelters was the building code DBN V.2.2-5:2023 (2023). It replaced DBN V.2.2.5-97 (1998), which had originally been a translation of the Soviet SNiP II-11-77 "Civil Defence Protective Structures". The new standard eliminated most Soviet terminology, such as "civil defence", replacing it with "civil protection", updated references to regulatory documents, and removed references to Soviet-era products for specific types of equipment. This allowed Ukrainian manufacturers and suppliers to offer their products freely (provided they did not

originate from Russia or Belarus). DBN V.2.2-5:2023 (2023) also introduced a new type of shelter – rapidly deployable protective structures – and defined specific requirements for each type of shelter (Fig. 2).

Figure 2. Categories of civil defence protective structures
Note: a – anti-radiation shelters; b – dual-purpose structures; c, d, e – varieties of simplest shelters
Source: Organising the sheltering of the population… (n.d.)

These types of defensive structures have of strategic importance for ensuring the protection of the population and belong to collective protection purpose. However, they do not cover all the protection needs of the population, considering the latest experience of living in wartime conditions (Fig. 1). Critical infrastructure, public buildings, and residential buildings suffer daily from air attacks by various ammunition, which continuously change while a war conditions. The main injuries in urban areas are shrapnel wounds from ammunition and fragments of destroyed building structures, as well as blast waves during the shelling of populated areas. The threats of air attacks that exist during the war will also remain in the post-war period. Therefore, the solution to the problem are in creating a modern, safe spaces for people. The Verkhovna Rada of Ukraine adopted the Civil Protection Code of Ukraine (2018), which stipulated that new housing constructed in Ukraine had to include its own bomb shelter or provide access to a nearby shelter. It also required that urban planning documentation at the local level include a section on engineering and technical measures for civil protection. According to the Civil Protection Code of Ukraine (2018) and Law of Ukraine No. 2486-IX (2022), the deployment of a network of bomb shelters in Ukraine was envisaged, including in all new buildings. Urban planning documentation had to include information on engineering and technical measures for civil protection; otherwise, it was not subject to approval. The law also stipulated that the state architectural and construction control authority could refuse to issue a certificate of readiness for operation if the developer failed to fulfil the required conditions for equipping bomb shelters. At the regional level, initial steps in this direction were already being taken. The Standards for High-Quality Housing… (2022) provided an example of recommendations developed and approved by local urban planning authorities regarding underground shelters, protected spaces in apartments and office buildings, features of engineering communications, life-support systems, and spatial planning. A new type of shelter was planned to be constructed for the first time in Lviv. Safe rooms based on the Israeli model were expected to be introduced in an office centre, following the Israeli example (In Lviv, a property developer…, 2023). This represented a positive practice, but only the beginning of the process of modernising legislation at the state level.

When discussing protective structures, it was important to understand that state standards (such as DBN V.2.2-5:2023 (2023)) did not cover all possible solutions for ensuring protection under real conditions. It was therefore necessary to consider and implement the best practices of countries such as Israel, Singapore, and others. For this reason, particular attention was given to those approaches that were directly relevant to the needs of Ukraine. Based on the above, the key question was what Ukraine should adopt from international experience. First and foremost, the implementation of a comprehensive range of small, yet equally important, shelters installed directly within public or residential buildings should have been regulated at the state level. Such premises could be collectively defined by the general term “protected space” – a type of shelter that could always be quickly accessed and provided rapid protection from most threats when reaching a “traditional shelter” was not possible.

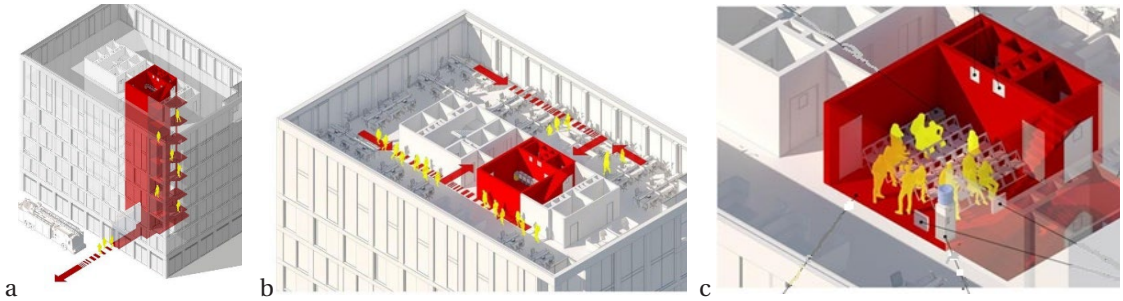

Figure 3. Principle of placing protected rooms in a building
Note: a – location within the building's rigid core, stacked one above the other; b – location deep within the building; c – functionality of the premises, providing amenities and everything necessary
Source: In Lviv, a property developer… (2023)

For example, if building has protected space within rooms or under the building, there no need to go outside to looking for official shelter, risking wounds or injuries from debris. The correct concept is not moving to a bomb shelter several blocks away or descend from the 25th floor to a basement under the building, but to have premises built as a protected armoured structure directly where people are located. And ensuring the presence of an elevator that will operate during power outages, and generator – as one of the requirements, without which the building will not be commissioned. For this purpose, legislation must be urgently adapted towards creating population protection. First, there must be types of protective constructions, like as temporary shelters, to allow people quickly find protection. Since there is no regulatory framework for designing protected spaces yet, the fastest and most practical option is to build shelters from prefabricated reinforced concrete structures. Figure 4 shows one such facility in the process and after construction.

The technical requirements for protected spaces in Ukraine are absent. They will not replace full-fledged civil defence protective structures, but as a supplement to them, or for organising people protection at the initial stage of danger, they will be extremely relevant. Figure 5 shows the principle of design-stage calculating a prefabricated explosion shelter, as well as a schematic diagram of how to assemble such a shelter. Regarding placement, it can be at ground level, buried, or semi-buried.

Figure 4. The simplest type of precast reinforced concrete shelter built at a factory in the Kyiv region
Source: Ruslan Kravchenko: Another modern shelter... (2024)

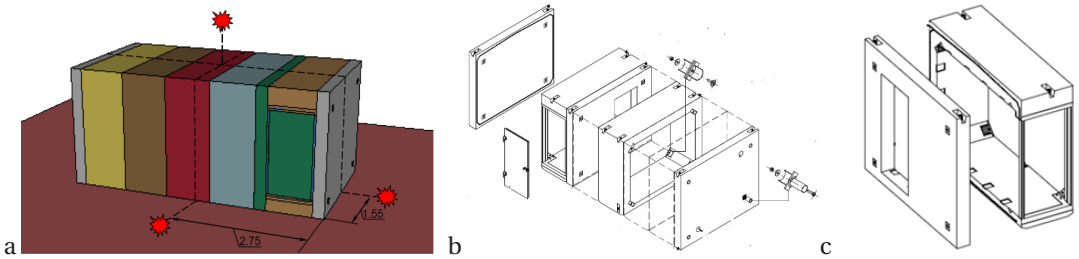

Figure 5. Prefabricated reinforced concrete shelters
Note: a – diagram of explosion points; b and c – structural elements of the construction
Source: I.M. Neklonsky (2017)

For industrial facilities, especially critical infrastructure sites where staff cannot leave their workplaces to take shelter in civil defence protective structures – even during threats – the situation is particularly challenging.

Although Ukrainian standards provide for anti-radiation shelters or dual-purpose structures at industrial sites, these requirements are not mandatory for most industrial enterprises, unlike in many other countries. Currently, shelters are actively being built for state-owned critical infrastructure enterprises using state funding (Hasenko *et al.*, 2025; Filonenko & Nikolaienko, 2025). However, in the private sector, this remains a rare exception. Such shelters are usually incorporated only when new facilities are designed in line with best international practices and current state requirements. When comparing a standalone shelter with a built-in dual-purpose structure, the latter is clearly preferable from a safety perspective (Fig. 6).

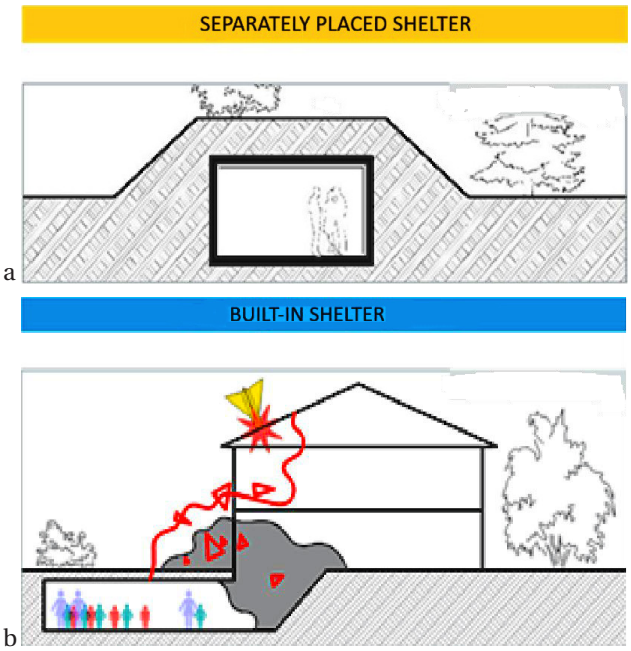

Figure 6. Types of shelters by location
Note: a – separately placed shelter; b – built-in-shelter
Source: S. Malliiani & O. Slietsov (2025)

For example, a built-in canteen, changing room, meeting room, or operator's room at the basement floor, that meets all the standards of shelter is significantly safer and more convenient, as personnel do not need to leave the building to take detached shelter. It reduces the risk of being exposed to shelling while moving from the workplace to an outdoor shelter. In the case of staff, this also means additional time for changing clothes, since, in winter, personnel must leave work change sanitary clothing with warm clothes before heading to the shelter (State comptroller of Israel, 2024). Also to be added that crowds of people need to change clothes simultaneously. Therefore, a shelter within an industrial building is not only safer but also more convenient, considering that dual-purpose structures already have the necessary comfort and amenities for extended stays. The economic aspect is important for industry. On the one hand, a dual-purpose structure seems to be a profitable solution for business, as there is no need to build a separate shelter, and one premise covers both current operational needs and shelter. On the other hand, the cost of such a premise might be higher than, as detached one. Because of the cost for additional equipment, emergency power supply, ventilation, strengthening of walls and ceilings, an additional exits arrangement – can make this option less attractive. An entrepreneur will choose a cheaper option, despite all the safety and convenience advantages. Ukraine's housing stock was quite diverse in terms of implementing the necessary reconstruction. For instance, in the case of monolithic-frame buildings, the required changes were not significant. Protected spaces were located inside the building next to elevators, where they were enclosed from all sides and did not face the façades. This corresponded to the "two-wall rule", whereby the first wall could be hit by a missile, while the second would protect against fragments. Ideally, such a room was designed in the middle of the apartment. According to Ukrainian standards (DBN V.2.2-5:2023 (2023)), "blind room" layouts were not yet provided. The protected room had to be properly organised, including the provision of ventilation, water and food supplies, and an emergency lighting system. In non-frame or existing buildings, such as inexpensive panel and brick structures, the implementation of monolithic-frame protected rooms could require an additional 10-20% investment relative to the property value (Recommendations from the State Emergency Service..., 2022). It should be noted that a safe space was more than just walls. It included the comfort of stay and the ability to remain there for an extended period. For example, the arrangement of shelters in educational and children's institutions involved spaces with bright designs and engaging themes to support children's psychological well-being. At the same time, any strengthening requirements increased costs. For the construction industry, this meant reduced profitability, while for residential construction it led to higher property prices and a potential risk of decreased demand. If a developer invested more in construction, they either earned less or increased the cost of the property. Therefore, the experience of other countries demonstrated the necessity of strengthening state standards for proper construction. It should also be noted that the implementation of new requirements needed to be supported by both state programmes and non-governmental funds aimed at facilitating the transition to functioning under military threats and adapting infrastructure accordingly (State comptroller of Israel, 2024). It is essential to develop a material, technical, legal, and financial framework that would ensure compliance with existing requirements and the adoption of new ones in line with current challenges.

During the study by S. Malliiani & O. Slietsov (2025), a phased analysis of civilian casualties caused by missile and drone attacks was conducted, and three most critical damage scenarios were identified: residential buildings, open spaces, and public facilities with mass gatherings. Based on these scenarios, a comparative analysis of the regulatory framework, spatial and functional parameters,

and typology of protective structures in Ukraine, Finland, and Israel was carried out. The study resulted in the identification of the strengths and weaknesses of each model and in the formulation of potential directions for modernising the Ukrainian system of protective structures. The current nomenclature of protective structures in Ukraine did not include solutions capable of effectively protecting the population under the first scenario – attacks on residential buildings. Unlike Ukraine, Israel had a deeply integrated model of Mamad and Mamak shelters, which formed part of the structural system of residential buildings and had regulated parameters of blast resistance, airtightness, and immediate accessibility. Given the similarity of threats, the implementation of adapted individual or floor-level shelters in Ukraine represented an appropriate and potentially life-saving solution. Under the second scenario – protection in open spaces – the Ukrainian system did not include regulated types of structures capable of providing effective protection in such conditions. In addition, relatively large regulatory accessibility radii (300-500 m) created additional risks when attempting to reach a shelter. In this context, fortified ground shelters of the S2 type (Mamak) were particularly relevant – mobile and spatially accessible modules placed in close proximity to public areas (50-100 m). In Ukraine, it would be advisable to develop a national model of ground shelters with an emphasis on modularity, mobility, and blast resistance. Under the third scenario – the presence of large numbers of people in public buildings (schools, theatres, shopping centres) – the current nomenclature of PRU and shelters in Ukraine provided a basic level of protection (Malliiani & Slietsov, 2025). However, it did not eliminate the fundamental risk associated with a high concentration of people within a single large space, which increased the likelihood of mass casualties in the event of a direct hit.

In contrast, the analysis of recent conflicts presented in The resilience of Israel safe rooms… (2025) showed that the wars in Ukraine, the October 7th War, and the 12-day war in Israel demonstrated that the residential protected room, while groundbreaking at the time of its introduction, was no longer adequate for evolving security challenges. Recent conflicts in Gaza, Ukraine, and Israeli urban centres indicated that concrete alone could not ensure safety. The collapse of surrounding structures could turn Mamads into sealed spaces with no escape routes. The lack of proper ventilation and emergency exits also made them potentially dangerous during fires or chemical incidents. O. Sliepstov & S. Malliani (2025) further argued that this type of shelter had become outdated and did not address new scenarios such as urban combat, combined threats, or earthquakes. A. Chudzińska *et al.* (2025) indicated that the most effective integration with the urban environment was achieved by shelters adapted within existing buildings or infrastructure, such as basements of sports halls, shopping centres, or transport tunnels. These solutions enabled the integration of civil protection functions with the maintenance of public order. In contrast, conventional shelters constructed from scratch outside urban centres required significant financial and infrastructural investment, making them difficult to replicate on a large scale in European conditions. Moreover, the ratio of costs to potential benefits, given population density, was often unfavourable. Large-scale protective facilities, such as the Sonnenberg shelter and the AT&T skyscraper, were designed to be fully autonomous and were equipped with electricity generators, air filtration systems, and long-term supplies of water and food. While they represented a high level of technical resilience, this was achieved at the cost of extremely high expenditures. From a historical perspective, the social function of shelters (criterion D) evolved from an exclusive to an inclusive model. The most advanced Cold War shelters were typically intended for elites, such as political and military leadership, and were not accessible to the general population. In contrast, contemporary approaches emphasised universality: in Finland, underground concrete shelters were accessible to the entire population, and legislation required their integration beneath large public buildings (Malliiani & Slietsov, 2025). The evolving dual-use concept of shelters raised the question of how new civic and recreational functions aligned with their primary life-saving purpose. S.H. Jore *et al.* (2025) examined the roles and perceptions of security guards in Norway, demonstrating that security and safety should not be reduced to traditional preventive measures (e.g., physical barriers and armed protection), but are instead constructed through a broader set of practices. The authors emphasised that contemporary safety is co-produced through diverse professional functions, including situational vigilance, inter-agency collaboration, elements of social support, and service-oriented activities, thereby framing security work as an integrated component of societal safety production. While everyday use improved maintenance and public acceptance, it should not have compromised emergency readiness. Maintaining this balance required regular system testing, personnel training, and public awareness to ensure that accessibility in daily use did not reduce effectiveness in emergency situations, as noted by L. Zhao *et al.* (2017). Thus, the emerging concept should promote inclusivity – shelters designed "for all, not the select few". In addition, the time required to reach a safe space remained a critical factor in ensuring effective protection.

Conclusions

The experience of air attacks, particularly in frontline areas in 2025, confirmed that even where technical evacuation measures were available, factors such as time, orientation, and route accessibility determined the success of self-evacuation. This further emphasised the importance of creating local shelters directly within residential buildings, providing immediate access to protected spaces without the need for complex navigation. The integration of residential protected rooms into existing buildings or civil infrastructure not only met the requirements of adaptive responses to contemporary risks, but also compensated for the limitations of traditional shelter systems. Thus,

the results of the study indicated that the Ukrainian civil protection system had real potential for development, but required updating, increased spatial accessibility, and a reconsideration of the principles governing the placement and organisation of protective structures in the context of residential development, open spaces, and public facilities. Taking into account behavioural factors in emergency situations, such solutions could become an effective complement to the existing network of protective structures. The implementation of pilot solutions within individual buildings or residential complexes would allow the technical feasibility and cost-effectiveness of such shelters to be tested under real conditions. The results of this stage could form the basis for updating building codes and developing practical recommendations in the field of civil protection as an important component of comprehensive population protection. If pilot projects were successfully implemented, the next stage would involve securing funding and creating conditions for the operation of funds dedicated to the construction of new shelters and the renovation of existing ones.

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Conflict of Interest

None.

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Впровадження світового досвіду будування укриттів цивільного захисту

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Анотація. Загострення сучасних військових загроз в Україні зумовило необхідність перегляду підходів до цивільного захисту та інтеграції захисних споруд у житлову й громадську інфраструктуру. Метою дослідження був аналіз українського законодавства поряд із відібраними міжнародними практиками задля виявлення ефективних моделей інкорпорації захисних просторів у будівлі та обґрунтування напрямів розширення класифікації захисних споруд. Методологічну основу становив комплексний аналіз національних нормативно-правових документів, порівняльна оцінка міжнародного досвіду, а також узагальнення й систематизація найкращих практик. Особливу увагу приділено законодавчим і технічним підходам, запровадженим в Ізраїлі та Сінгапурі, зокрема щодо інтеграції укриттів у будівлі, забезпечення швидкої доступності та функціональної ефективності. Дослідження також враховувало економічну доцільність і практичні аспекти впровадження таких рішень в існуючих та новозбудованих об'єктах. Результати показали, що міжнародна практика послідовно наголошує на критичній важливості мінімізації часу, необхідного громадянам для доступу до укриттів. Це досягається шляхом вбудовування захищених просторів безпосередньо в житлові та промислові будівлі або завдяки розгортанню модульних систем укриттів. Проаналізовані приклади засвідчили, що такі підходи забезпечують вищий рівень безпеки населення, особливо в умовах частих і непередбачуваних загроз. Встановлено, що як Ізраїль, так і Сінгапур успішно закріпили ці рішення у своєму законодавстві, підкріпивши їх чітко визначеними технічними стандартами. Дослідження обґрунтувало доцільність поступового впровадження інтегрованих і модульних захисних споруд в Україні – як у процесі післявоєнної відбудови, так і в нових будівельних проєктах. Практичне значення роботи полягає у розробленні рекомендацій щодо адаптації українського законодавства та підвищення доступності, ефективності й стійкості інфраструктури цивільного захисту

Ключові слова: захищений простір; споруди подвійного призначення; міська стійкість; підземні простори; Мамади