CIRCULARITY IN DEFENSE AND PROTECTION AGAINST HYBRID WARFARE

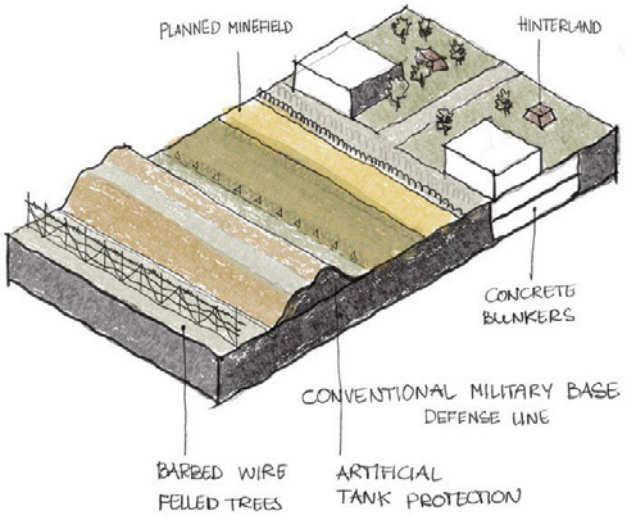

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TABLE OF CONTENTS

1. INTRODUCTION

1.1. PROBLEM STATEMENT

Rising geopolitical tensions, increasing state-based armed conflicts, high levels of violence and displacement combined with the climate emergency are man-made factors of disasters, which also become drivers of humanitarian needs worldwide. According to Global Humanitarian Overview 2026 from Humanitarian Action, over 239 million people are in urgent need of humanitarian assistance and protection due to conflicts, many of which last longer than before (Cavalcanti, 2025). Numbers of civilian deaths are hitting record numbers and are associated with hunger, displacement, disease and devastation of mental and physical health. International Humanitarian Law is often violated, raising levels of international crimes and negatively affecting protection of civilians everywhere. Nuclear weapons are another significant threat, currently becoming at heightened tensions (Messmer et al., 2023).

Moreover, emergence and widespread use of Artificial Intelligence (AI), technological connectivity and digitalization affect disasters in a new, previously unforeseen way. From fake artificially generated news or videos to instant spread of propaganda, polarizing societies even more. It reinforces the narrative of us versus the enemy, setting people against other nationalities. Digital technologies are also becoming a part of warfare, such as the use of drones or AI-assisted weapons, which amplifies the already-existing risks, due to their higher ranges and accuracy (United Nations, 2025; Arms Control Association, 2023). Integration of artificial intelligence within nuclear weapons is another serious concern, connected with the unknown risks and possible disastrous, catastrophic mistakes.

1. Stages of peace and conflict. Current geopolitical conditions indicate rising tensions and increasing instability.

Other than direct application, digitalization and connectivity also affect perceived sense of safety of civilians; news is delivered instantly in one click of the screen to any part of the world, bringing the war straight into the house. Furthermore, digitalization and high reliance on technology have made people more vulnerable in case of blackouts or other possible shortages, thus affecting resilience and human ability to deal with emergencies. According to Scientists for Global Responsibility, Global Greenhouse Gas Emissions of the military account for approximately 5.5% of total GHG emissions, but this is limited to only peacetime operational and supply-chain emissions. Even with this number, if military GHG emissions were a country, it would have the fourth largest national carbon footprint in the world (Parkinson et al., 2022). Many of these emissions are included in civilian expenditures or much of it is not submitted at all, inculding the top three military spenders: US, China or Russia. It seriously undermines climate-related ambition and dealing with climate emergency (ConEnvObs, 2025). Data from 2025 indicates that over three years of war in Ukraine, more than 230 Mt CO2 emissions were released (Igini, 2025). Furthermore, wars start a new chain of reconstruction and rebuilding that in turn releases even more carbon dioxide emissions.

Thus, the most sustainable form of defense is the prevention of conflict itself. When prevention is not enough, circularity becomes central to the discourse of protection — raising the questions of resilience, renewable resources, material reuse and continuity of life.

This research paper investigates the threats of armed conflicts and their overlap with digital crisis and misinformation, tackling a new type of war: hybrid war. Hybrid war is a war fought by both the conventional military methods and techniques such as cyberwarfare, spread of disinformation, and the use of paramilitary forces. Current research lies in protective and preemptive measures that can be undertaken for common safety, with deeper focus on circularity within protective structures. The research describes how sustainability within defense can not only prove beneficial for the environment but also facilitate in defense.

The research question therefore is: **How can circularity facilitate civilian protection and defense in times of hybrid warfare?**
The paper will also investigate the following sub questions:

1. How can architecture aid civilian protection in times of armed conflicts and digital threats?

2. What are most common issues with conventional protective structures?

3. What circular design principles can be introduced in designs related to armed conflicts and defense?

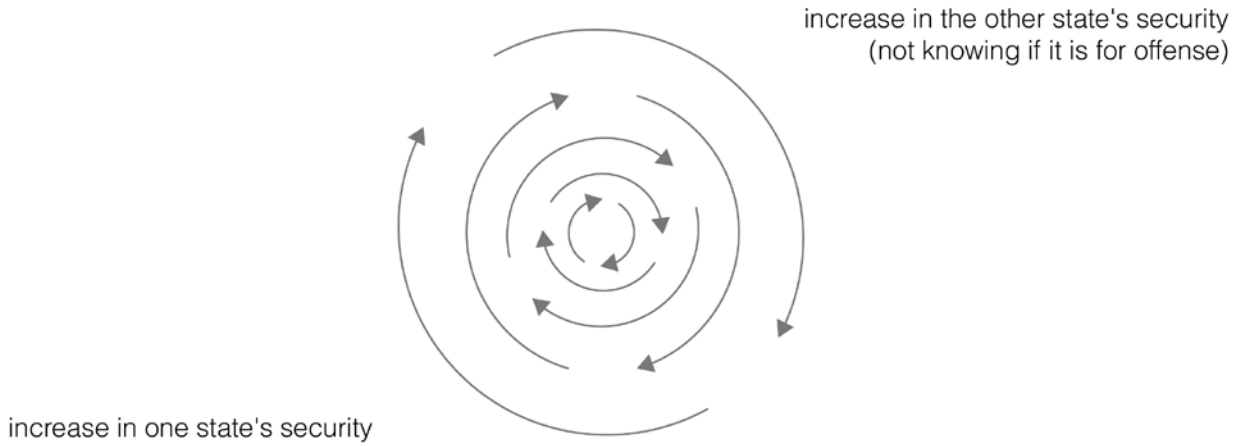
1.2 RELEVANCE

In the realm of increasing defense spending and militarization happening in Europe, sustainable development goals are often postponed, reaching back for damaging practices that led us to the state of planetary emergency. Europe responds to Russian threats by actively strengthening their defense, which Russian is using for propaganda. We entered a so-called security dilemma. (Fig.2)

Contribution of architects in the design of military bases is limited, and military engineers continue tackling the issues in familiar yet unsustainable ways: cutting down forests, disturbing landscapes, using materials with high carbon dioxide emissions, and building monofunctional structures that eventually lie abandoned. Design of military bases lies in the ethical grey zone of protection and is strongly stigmatized, meaning it rarely has enough attention and space for improvement. Current research focuses on finding ways to reimagine defense solutions through circular practices instead of hostile enclosed structures.

1.3 SCOPE

Scope of this research lies in creating an overview of existing protective measures, from conventional defense to the protection against cognitive warfare, and how those can be undertaken with sustainable development in mind. The paper aims to show the potential of circularity applied to protective structures and define possible implementation of these changes.



2. Security dilemma

2. METHODOLOGY

For the research paper, literature review and case studies serve as the main source of information. Existing research was used to understand the themes of environmental impact of conventional military bases and identify issues with existing typologies that prevent future reuse. It drew on multiple aspects of protection, starting from conventional defense structures to cognitive protection. Based on multiple research papers, several categories of circular interventions in built environment were identified. The overlap between protection requirements and circular principles defined in research paper formed design principles for the upcoming project.

3. RESULTS

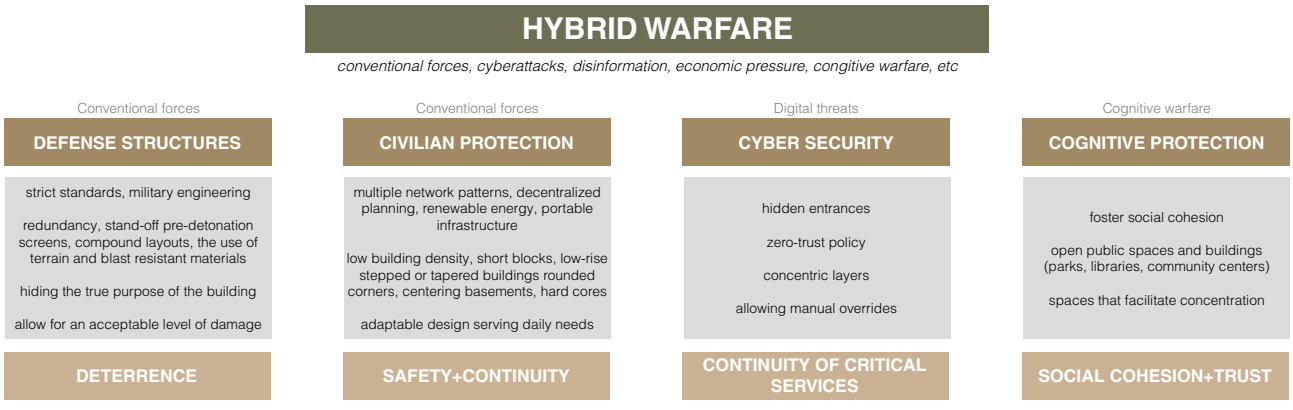
3.1 DEFENSE IN HYBRID WARFARE

Hybrid war is a war fought by both the conventional military methods and techniques such as cyberwarfare, spread of disinformation. Threats are no longer merely kinetic but include non-kinetic and cyber threats that aim to disrupt critical logistics (NATO, 2026).

Another essential element of hybrid disruptions is cognitive warfare – a novel aspect of conflict that exploits human cognition and digital technology to influence and manipulate how people process information and make decisions. As defined by North Atlantic Treaty Organization (NATO), cognitive warfare is the sixth domain of war, meant to destabilize populations that would ultimately be willing to lose without a fight (NATO, 2026).

Therefore, protection against conflict in XXI century needs to be reinterpreted. Other than conventional defense structures meant to deter and defend against the opponent, current protection must focus on cyber security, inner calm, cognitive autonomy and resilience of population (NATO, 2026).

Built environment can facilitate various kinds of protection, from physical to fostering social cohesion and inner resilience. (Figure 3)

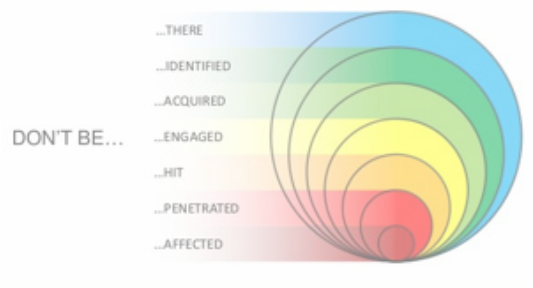


3. Hybrid warfare combines conventional military force with cyber, informational, and cognitive threats

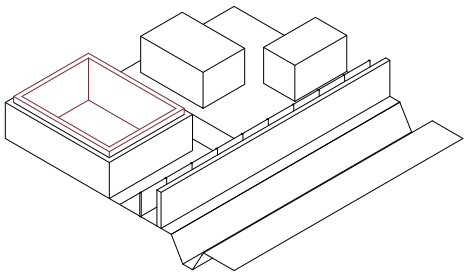
3.1.1. CONVENTIONAL DEFENSE STRUCTURES

According to TNO, protective structure design focuses on competing design requirements: from protection to human comfort, from cost and time to circularity. Protective structures are designed to withstand various levels of exposure, defined in military engineering as survivability onion (Figure 4). In built environment, these requirements particularly focus on blast protection, preventing penetration and ensuring safety of those within the building (TNO, 2025)

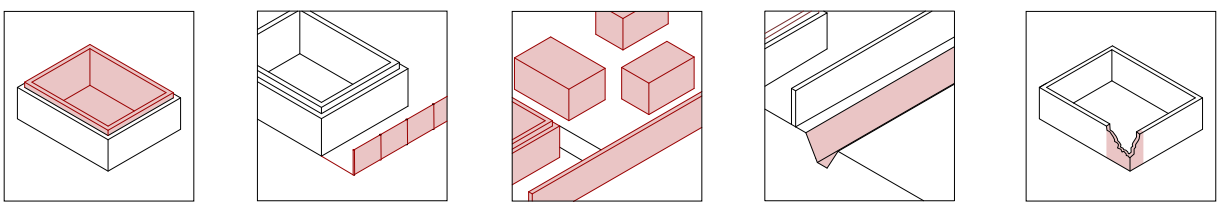
According to Defense Standardization Advice, defense structures have strict guidelines that are conformed with by military engineers (UK Ministry of Defence, 2021). Construction requirements within defense include primarily system resilience and redundancy, stand-off pre-detonation screens, compound layouts, the use of terrain and blast-resistant materials. Other methods include hiding the true purpose of the building or its proportions, reducing potential targeting (Figure 5). Most importantly, designing for protection in case of attack must allow for pre-decided acceptable level of damage to occur with minimal risks (TNO, 2025).



4. Survivability onion. Adapted from Dodge and McKelvey (2013)



CONVENTIONAL DEFENSE STRUCTURES



REDUNDANCY

STAND-OFF PRE-DETONATION SCREEN

COMPOUND LAYOUTS (FORTIFIED, SELF-CONTAINED, ENCLOSED)

USE OF TERRAIN

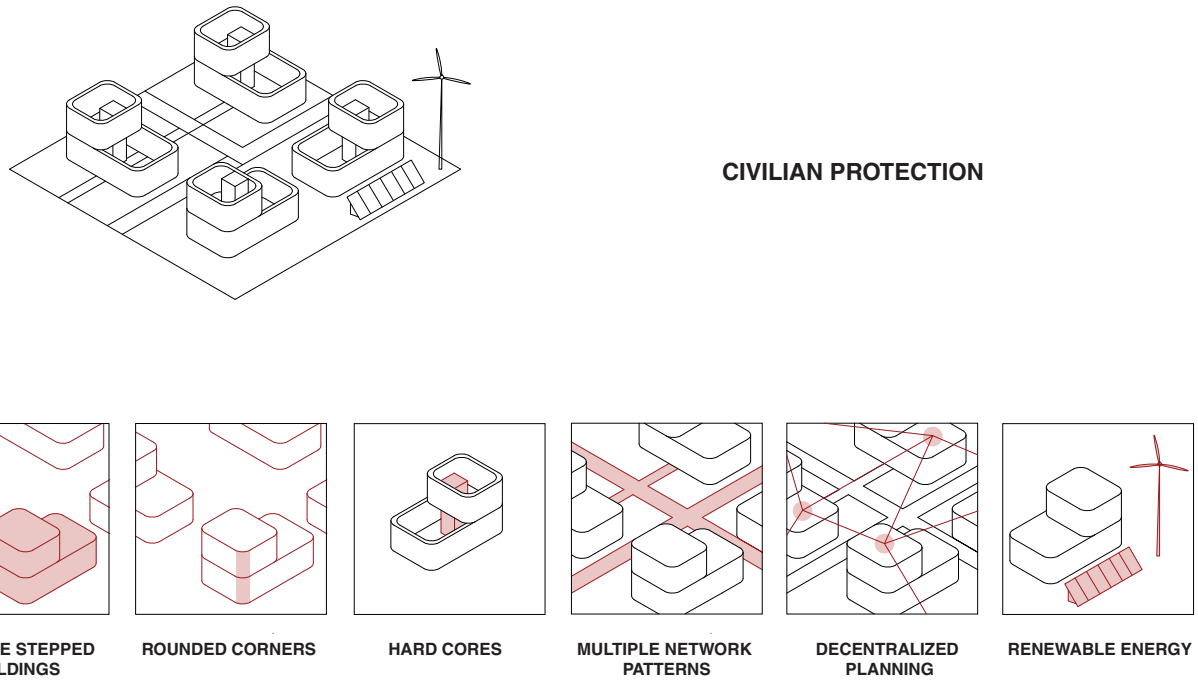
ALLOW SOME DAMAGE

5. Key spatial principles of conventional defense

3.1.2 CIVILIAN PROTECTION: DESIGN CONSIDERATIONS

In the past decades, more cities have been affected by armed conflicts due to urbanization. Critical infrastructures are located in highly dense environments, which furthermore affects city fatalities in armed conflicts (Hassein, 2025). Civilian protection requirements focus on protecting individuals who are not taking part in hostilities from murder, torture and degrading treatment. It is rooted in International Humanitarian Law, a set of rules that seek to limit the effects of armed conflict (ICRC, 2024).

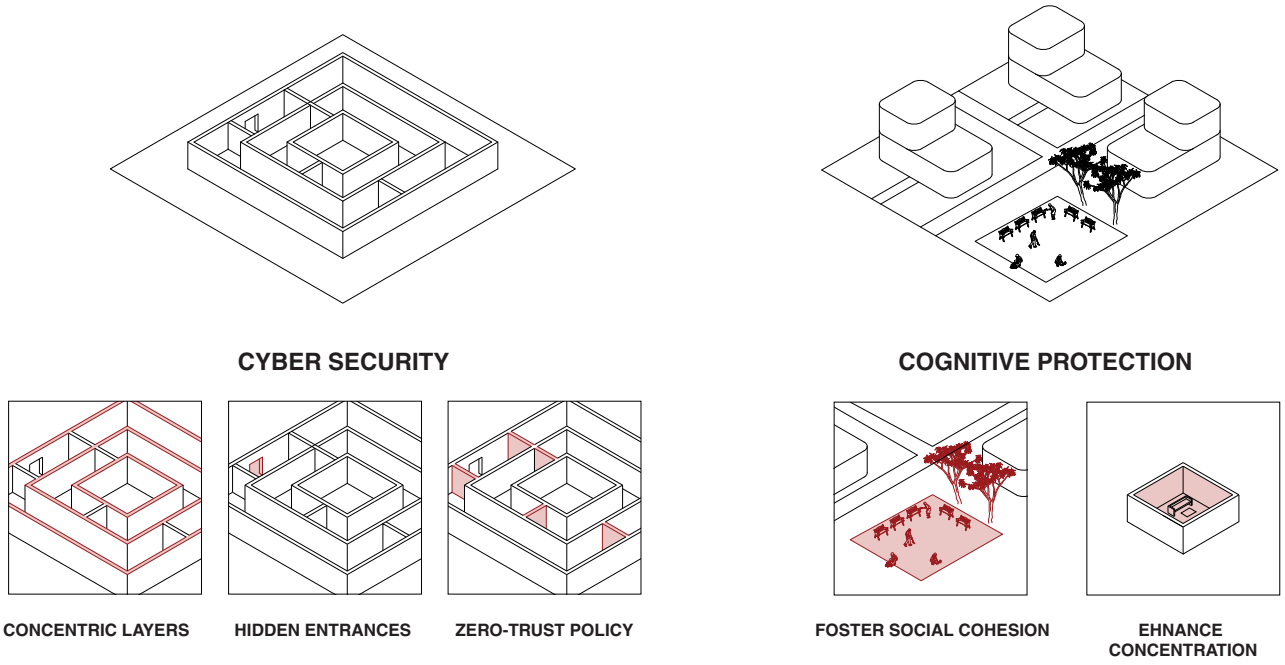
In built environment, this increases the need for resilient to extreme condition frameworks within the cities, as well as passive defense strategies. Such elements include naturally protected sites, maintaining low population density, using multiple network patterns and T-junctions, and using unpredictable polycentric distribution of targets. The use of renewable energy and portable infrastructure offer systems resilience. Homogenous short blocks with low building density and point-building typology, low-rise stepped or tapered buildings with rounded corners, centering basements, blast-resistant structural systems and blast-resistant materials and coatings (Hassein, 2025). Moreover, using networks for evacuation and adaptable designs that serve daily needs while functioning as shelters, offer civilian protection in parallel with daily life (Ene et al., 2024). These principles are summarized in Figure 6.



6. Civilian Protective Principles

3.1.3. CYBER SECURITY

Over the past century, the nature of war has changed, and critical infrastructures become vulnerable through the realm of cyber security and cyber-attacks. Digital threats refer to non-kinetic threats, usually aiming at disruption of critical logistics. In cybersecurity, physical protection of essential facilities is the first step of protection (Figure 7). It includes hidden entrances, zero-trust policy for each entrance, concentric layers with critical infrastructure in the middle (Ubique Security Risk Management, 2025). In other systems protection from digital threats includes functioning despite cyber disruptions, having digital twins and secured systems with possibilities of manual overrides for more secure functioning in case of an attack. Moreover, cyber security needs to ensure that means of communication that exist are still safe.



7. Cyber security and cognitive protection principles

3.1.4. COGNITIVE PROTECTION

Architecture can be tool of oppression in dictatorship, reinforcing propaganda and polarization, distorting the truth. Removing benches from the cities, installing additional fences, and limiting open public spaces to prevent potential crowds in protests, democracy and possibility of exchanging opinions is excluded from the city (Deutinger, 2018).

While architecture cannot directly protect from cognitive warfare, it can provide spaces that foster social cohesion. By providing public gathering zones and buildings that lead individuals to stronger community bonds and belonging, such as parks, libraries, or community centers (Qi et al., 2024), population becomes more resilient towards misinformation and cognitive warfare,

due to exchange of ideas and discussions, that allow for expanding political views. Furthermore, overlap between architecture and neuroscience allows to design spaces to prevent cognitive decline, facilitate concentration and human well-being (De Paiva, 2024), letting to sharpened critical thinking (Figure 7).

3.1.5. CONCLUSION: REQUIREMENTS FOR PROTECTION

From physical protection to cognitive sharpening, architecture has a possibility to provide protection against hybrid warfare on multiple scales. On macro scale, built environment can provide redundant and hidden infrastructures that secure resilience of systems in case of attacks, preventing shortages or blackouts. Polycentral planning and decentralized zones enhance safety through unpredictable distribution of targets. Compound layouts and stand-off distances offer increased safety both in conventional defense structures as well as civilian protection. Furthermore, the use of rounded shapes shows higher resistance to explosions, therefore providing higher safety. Accessibility of public shelters that alternatively function as spaces of social cohesion can foster resilience and human well-being, therefore bringing people together, protecting them from cognitive manipulation. Knowing the criteria that make a community resilient in case of extreme conditions (in this scenario – in case of armed attacks), create high level of preparedness and ultimately deterrence, making specific communities an unappealing, costly aim, preventing the potential conflict. Public spaces are scientifically proven to increase community resilience in times of uncertainty and vulnerability (Zarkhah et al., 2025), and libraries serve as an important tool in public knowledge and protection in times of disruption.

3.2. CIRCULAR DESIGN PRINCIPLES OF PROTECTIVE STRUCTURES

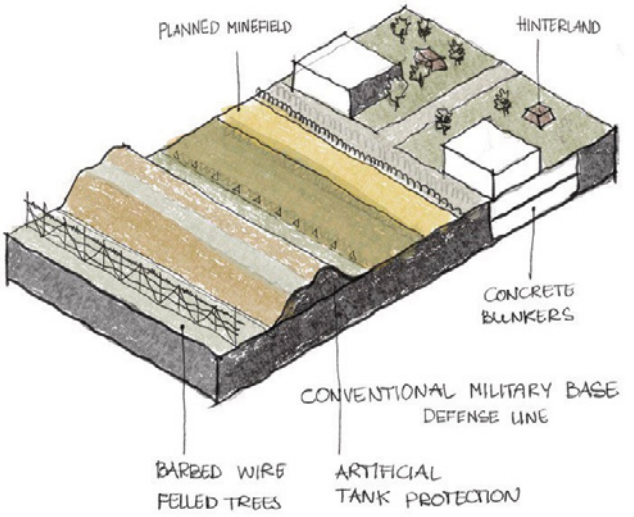
According to Scientists for Global Responsibility, Global Greenhouse Gas Emissions of the military account for approximately 5.5% of total GHG emissions, but in reality this number is much greater. If military GHG emissions were a country, it would have the fourth largest national carbon footprint in the world (Parkinson et al., 2022). Many of these emissions are included in civilian expenditures or much of it is not submitted at all – the top three military spenders (US, China

or Russia) are either not submitting data or submitting it incomplete. It seriously undermines climate-related ambition and dealing with climate emergency (ConEnvObs, 2025). Even in the beginning of 2025, over three years of war in Ukraine, more than 230 MtCO2 emissions were released (Igini, 2025). Furthermore, wars start a new chain of reconstruction and rebuilding that in turn releases even more carbon dioxide emissions.

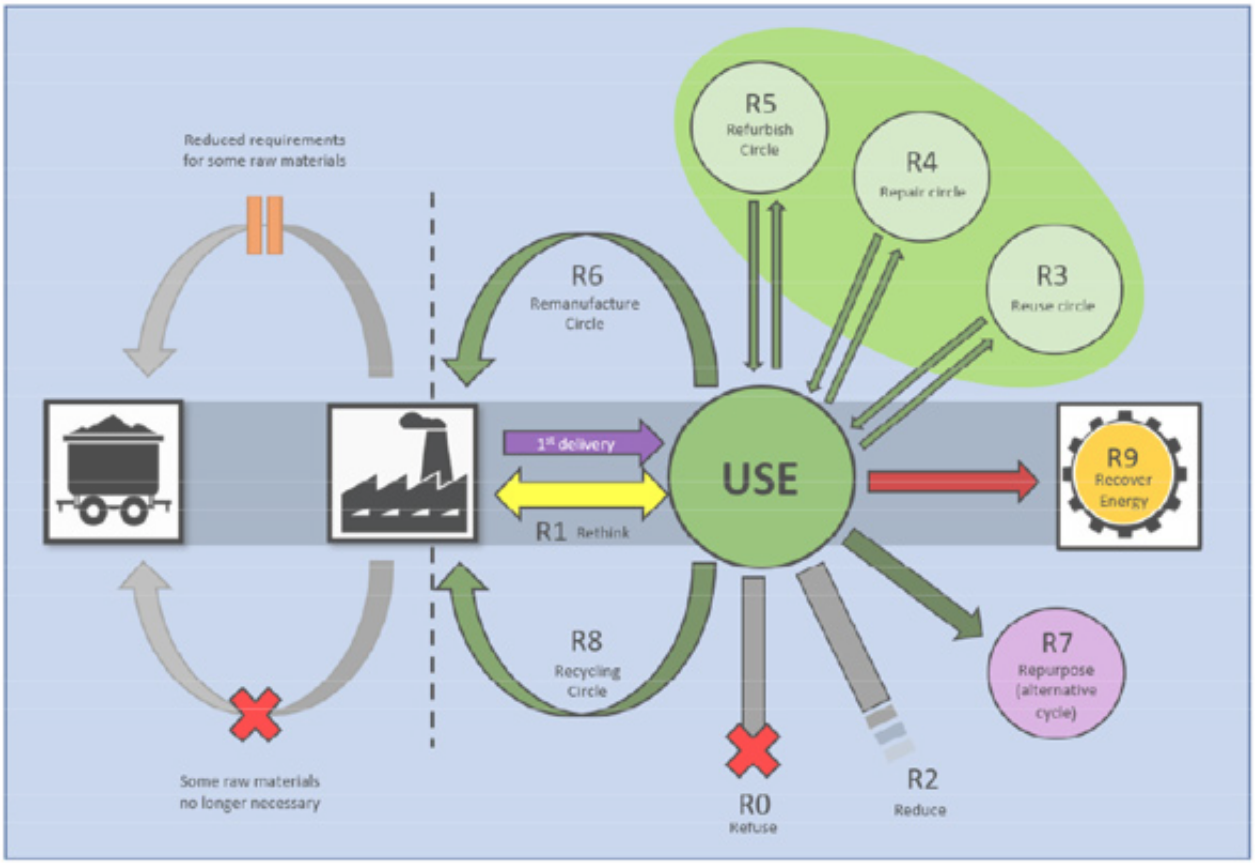
Hence, primary way to deal with carbon emissions would be to eliminate armed conflicts, since those rely heavily on massive fossil fuel consumption, generate and leave toxic contaminants, drastically disrupt landscapes and negatively impact biodiversities and human health (Messmer et al., 2023). Amongts polluting factors, military bases are some of the largest polluters within built environment and are an essential component of defense within countries. Therefore, reinterperting built environment and protective structures, as well as seeking sustainable means of civil protection are essential to tackle climate crisis. If societies are resilient and protected from high amounts of damage, overall CO2 emissions associated with military will subsequentially decrease.

3.2. CIRCULAR DESIGN PRINCIPLES OF PROTECTIVE STRUCTURES

With the climate emergency being an urgent issue in contemporary world, more advances are made in sustainability within protective structures. UK Ministry of Defense proposed circular economy strategy that would successfully tackle R-strategies within Defense in the way depicted in Figure 9. In this note, Ministry of Defense mentions that recycling within defense is already applied, however it should be tackled as the last resort, since all the former R-strategies are overlooked. Moreover, end-of-life logistics are rarely thought of, which is a crucial aspect of sustainability and recovery of materials from the cycle.



8. Conventional defence structure: enclosed compound layout with stand-off zones, terrain use, redundancy, and controlled access.



9. Circular economy strategies in defense (UK Ministry of Defense, 2025)

Netherlands is actively tackling energy transition within defense, where they outline in the document the direction for reduction of CO2 emissions within military construction and aim to achieve the greatest progress during maintenance to existing buildings (Miniserie van Defensie, 2024).

Other than advantages for climate emergency, circularity in defense structures offers benefits for the defense itself. First, infrastructure resilience is a crucial aspect that depends heavily on electricity needs and energy-intensive processes. Microgrids, portable solar/ wind systems, energy storage and sustainable fuels enhance operational flexibility, improve resilience and lower reliability on raw materials, increasing independency of potential shortages. (Heidecke et al., 2025) Sustainability in defense can increase readiness and resilience, as well as autonomy, improving civilian protection and ensuring continuity.

Potential directions for circularity in defense include (Figure 13):

3.2.2.1. AVOIDING NEW MATERIAL DEMAND: REUSE EXISTING STOCK

Retrofit

Retrofit is an improvement work on an existing building that aims to advance its performance while maintaining the existing function (Figure 10). In comparison to regular maintenance,

retrofit introduces new technologies or features into the building (Balasbaneh et al., 2025).

Since more urban citizens are affected by armed conflicts, retrofitting is an essential means to heighten protection levels of civilians. According to the research concluded after 100 days of war in Ukraine, main damage occurred from blast wave effects, fire, and bullet or shrapnel damage. The authors of the paper write: «Direct damage included destruction, cracking, distortion and declination from the axis of symmetry, damage to window glasses and frames». Overall, during armed conflicts highest damage occurs to the windows, door frames and the roof. Therefore, roof-level retrofits prove to be beneficial when protecting against conflict (Heidecke et al., 2025). Moreover, by ensuring that energy absorption from impact happens at the level of envelope will keep structure safe, thus protecting the entire building.

For conventional defense structures, retrofit could focus on reusing decommissioned military bases that already have required features for defense infrastructure. Main challenge of retrofit in military structures are the requirements with which defense systems must comply, thus prioritizing new construction.

10. Retrofit diagram

Adaptive reuse

Adaptive reuse is a sustainable practice of repurposing existing buildings. By repurposing abandoned or underused buildings, carbon emissions can result in 20-40% saving in CO2 emissions compared to new construction (Jamestown & Phillips, 2025).
By using the practice of adaptive reuse to design defense structures, implementing dual-use becomes a practical solution due to the former function of the building already suggesting opportunities.

3.2.2.2. EXTENDING LIFESPAN

Design for adaptability

When designing for adaptability, spatial order needs to be flexible to adjust the functions depending on the needs. Designing for adaptability is a future-proof-approach that should allow reconfigurations, extensions, or partial dismantling (Mlote et al., 2024). It also includes smart positioning of services, vertical circulation, adequate floor-to-ceiling height, structural grids. Scenario planning can help visualize potential futures. Design for adaptability is accounting for the potential adjustments to make future adaptive reuse effortless.

In context of the defense structures, design for adaptability may include transformations happening during the conflict, too, to avoid increased levels of danger in some parts of the building compared to others.

Upgrading pathways (improving protection without demolition)

In case of damage, an alternative route and infrastructure should be readily available, much like in fire safety protocols (Mohammadgholibeyki et al., 2023). This measure prevents the need to use extra resources for providing new infrastructure, thus extending lifespan of the existing structures.

3.2.2.3. CLOSE MATERIAL LOOPS

Design for disassembly

Design for disassembly focuses on designing products in a reversable way, that allows dismantling them without reducing the value. To make it feasible, designing for disassembly often involves time constraints, has to be simple and relatively fast (Ottenhaus et al., 2023).

Reclaimed materials and components

Reusing previously used materials and components from other buildings is another application of circularity in built environment.

11. Resource Rows, Copenhagen (photo&Project: Lendager Studio)

3.2.2.4. REDUCED EMBODIED CARBON

Material efficiency and structural optimization (such as parametric design)

There is emerging in the last years research that focuses on fiber-reinforced polymer matrix composites used for defense armor, while other papers tackle potential use of bio-based polymers in advanced military applications.

Use of low-carbon materials

Abundant research lies on exploring renewable, low-carbon materials, such as hempcrete, timber or rammed earth. Low-carbon materials offer lower carbon footprint throughout the entire life-cycle, and can be renewed. Manufactured materials are an alternative solutions where sustainable alternatives can be manufactured, such as geopolymer concrete (Farooq et al., 2021). Investigating the use of this material allows to significantly lower the carbon footprint related to defense (Ricciotti et al., 2025).

12. Hemcrete blocks, exhibition, Eindhoven (photo and project: Werkstatt)

Multi-functional elements

By incorporating multi-functional elements, less elements need to be produced overall, thus optimizing material usage (Sebastiani et al., 2024).

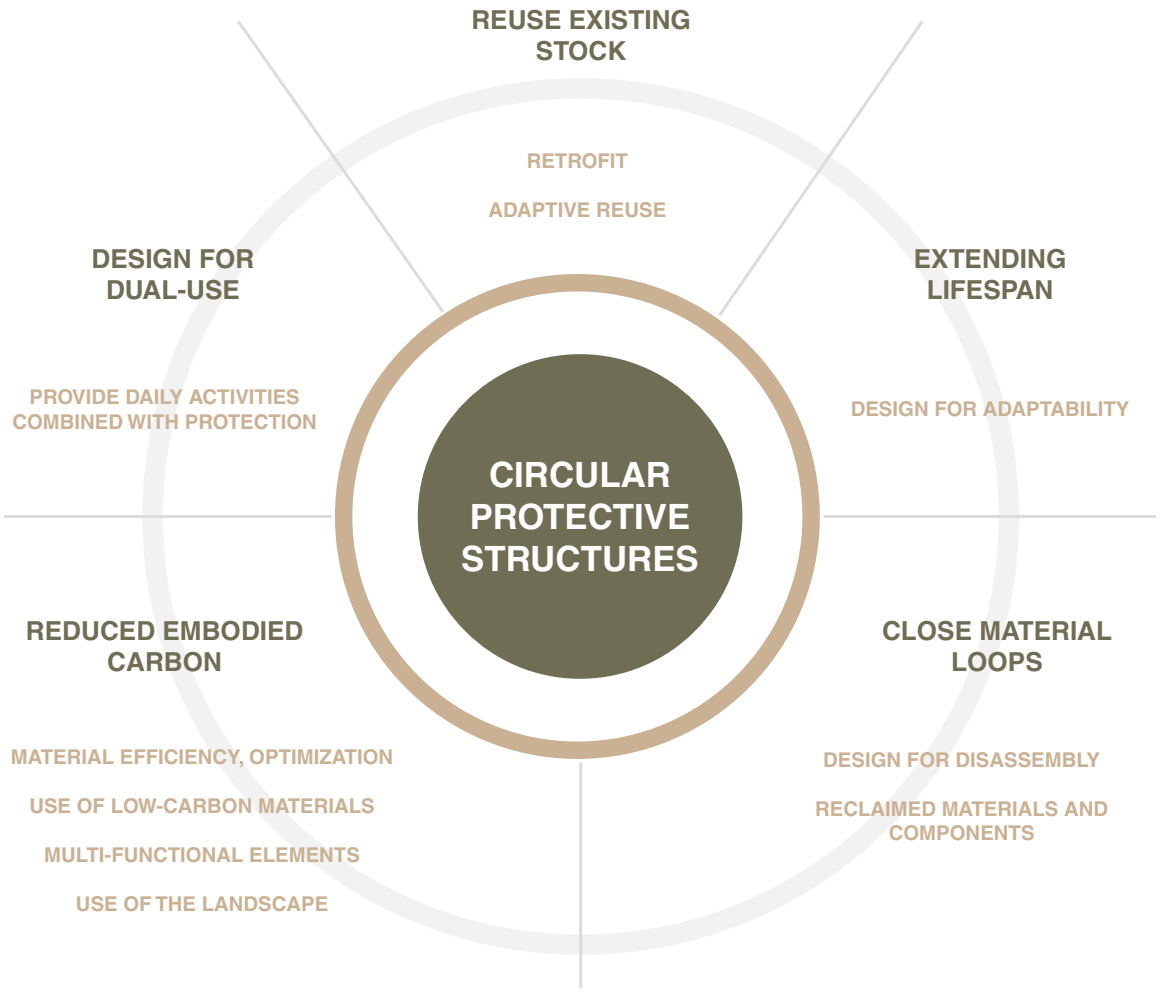
3.2.2.5. DESIGN FOR DUAL-USE

After the end of wars and stabilizing the world, many military bases and defense structures remain derelict, being especially vivid in the countries of post USSR. Military bases, originally designed with a single military function in mind, are failing in times of political changes and loosened tensions (Vafaie et al., 2023).

Design for longevity focuses on withstanding the challenges of time. Overdimensioning of structure or technical spaces, focusing on environmental impact of this material use, allowing for easy maintenance and replacement of building layers (Ostapska et al., 2024).

3.2.3. MICROGRIDS

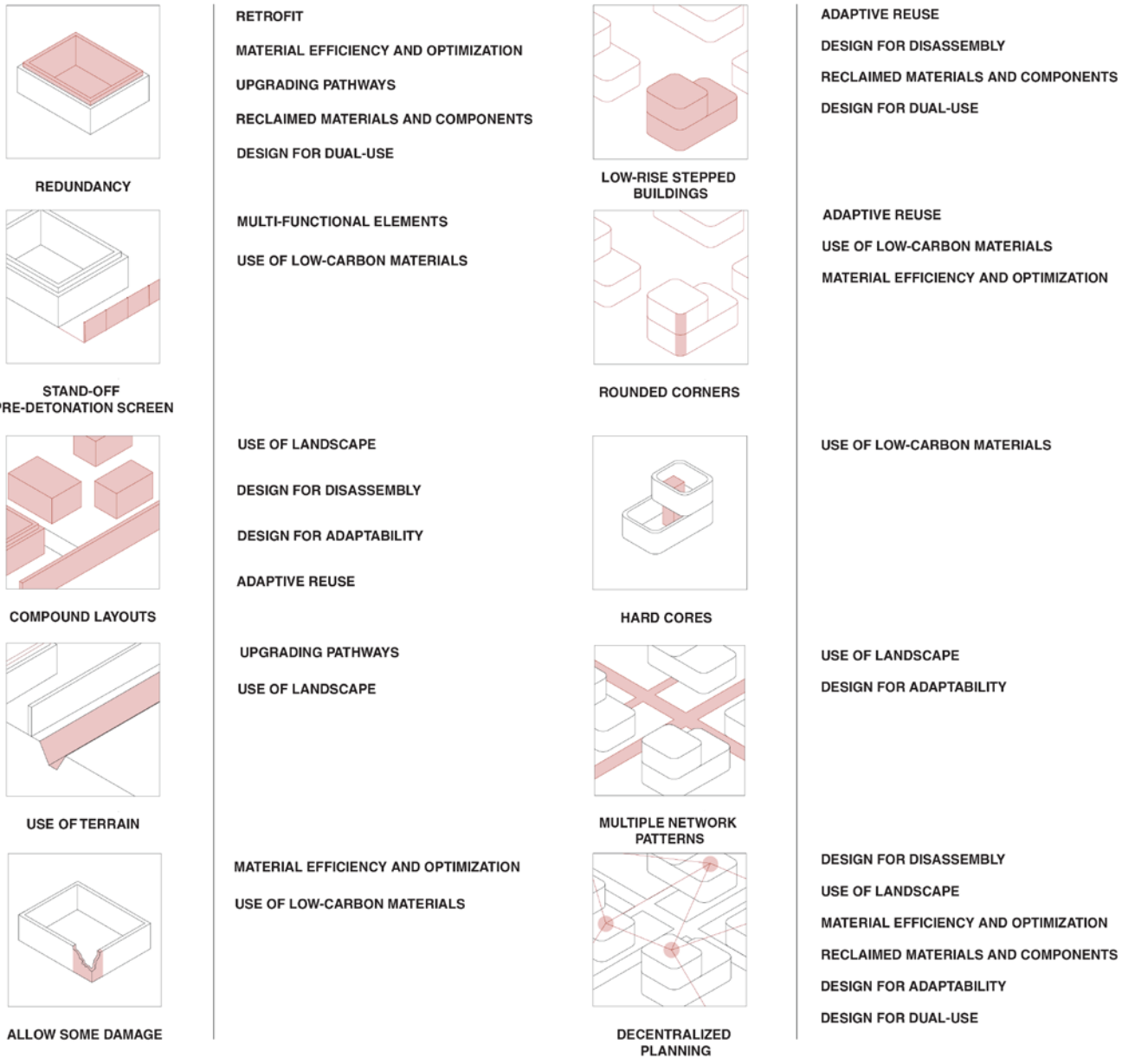
The use of microgrids in defense-related structures, battery storage systems combined with photovoltaic panels, wind turbines and alternative sources of renewable energy, allow making a structure self-sufficient and offer continuity in crisis, in case of damage of the main infrastructure (Miller & Kofman, 2022).



13. Circular Protective Structures Principles

5. CONCLUSION

As a conclusion of the research, circularity was identified as a crucial aspect of protection, providing resilience and continuity of life. It offers benefits both for energy-heavy operational flexibility, as well as for civilian protection (UK Ministry of Defence, 2025). By incorporating circularity in defense, a state increases readiness, resilience, and autonomy of its population. Main circular principles in defense overlapped with protective principles are outlined in Figure 14.



14. Circular Protective Structures principles corresponding to Protective Principles

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