

# Systemic resilience in disaster medicine: Personnel vulnerability and digital transformation in German civil protection

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## Abstract

German civil protection faces a resilience crisis driven by a fragile volunteer base and escalating disaster complexity. Empirical data indicates that only one third of volunteer responders are available during emergencies, often due to the "critical infrastructure paradox" — where responders are simultaneously essential workers in vital sectors. A dual-pronged strategy for systemic resilience is proposed. Structurally, it advocates for a uniform national legal status for responders and mandatory registers to manage dual-role conflicts. Technologically, it positions digitalization as a "force multiplier," emphasizing telemedicine (TeleSAN), resilient satellite-based communications, and the establishment of a national Mass Casualty Incident (MCI) Register. While predictive algorithms (LIFE-Triage) and generative AI offer transformative potential for dynamic triage and resource allocation, they must supplement, not replace, human ethical deliberation. Synergizing a reinforced workforce with robust digital infrastructure is essential for mastering future cascading crises.

**Take-home message for students** Resilience is about availability and infrastructure. While embracing digital tools - like telemedicine and predictive triage are essential "force multipliers", future disaster management requires a synergistic approach combining stabilized human resources with redundant, off-grid digital technologies.

## Introduction

In an era increasingly characterised by complex and cascading crisis events—be they pandemics, extreme weather phenomena driven by climate change, or geopolitical instabilities—the resilience of national security systems has become a central focus of academic and political discourse. A key pillar of this resilience is the framework of civil protection, which in nations like Germany has traditionally rested, to a significant extent, on the foundation of voluntary service. While this model fosters broad societal engagement and a highly motivated corps of responders, it also harbours systemic vulnerabilities that can become critical during a major incident. The central challenge lies in the actual, real-world availability of the personnel who are nominally registered and trained for emergency response.

In the following the dual challenges faced by the civil protection system are presented: firstly, an increasingly fragile personnel base, which is under pressure from socio-economic realities such as professional obligations and demographic shifts; and secondly, the imperative to manage the escalating complexity of modern incident scenarios. The corresponding solution must therefore also be a dual-pronged strategy. It requires, first, a fundamental structural and political reinforcement of the voluntary service framework. Second, it necessitates the consistent and strategic implementation of digital technologies, data-driven processes, and artificial intelligence (AI), which can function as 'force multipliers' to maximise the efficiency and effectiveness of the available human resources (Koncz et al. 2019).

## 1. The empirical reality: Personnel availability in a crisis

All strategic planning within the sphere of civil protection must be predicated on a realistic assessment of the human resources available. Recent empirical research into the availability of emergency responders paints a sobering picture, revealing a significant disparity between theoretical personnel strength and practical operational reality. The core finding of these investigations can be succinctly summarised: merely one-third of volunteer responders are fully available at any given time (Berliner et al. 2025). This figure alone presents a fundamental challenge to established alarm and deployment protocols.

A detailed analysis of the impediments to availability uncovers deep-seated systemic conflicts. At approximately 31%, civilian professional obligations represent the most dominant reason for non-availability. This fact highlights the inherent conflict of objectives between the necessity of maintaining the civilian economy and workforce, and the acute need for responders during a disaster.

Of even greater strategic importance is the second finding: around 27% of unavailable responders are employed in their primary occupations within critical infrastructure entities. This exposes a perilous systemic paradox. Critical infrastructure entities—encompassing sectors such as energy and water supply, healthcare, telecommunications, and logistics—forms the backbone of a functioning society, and its continuity is of the highest priority, particularly during a crisis. The fact that a substantial portion of the volunteer force designated for crisis management is simultaneously indispensable for the operation of these vital sectors creates a direct competition for human resources. This "dual-role" problem can lead to an unforeseen paralysis in

an emergency, as individuals are forced to make an impossible choice between their professional duties and their voluntary commitments.

Further factors, such as familial obligations (approx. 22%), complete the picture of a human resource whose availability is contingent on a multitude of external variables. Structural inequalities within the system — for example, in the legal provisions for release from employment, which are historically more robust for fire brigades and the Federal Agency for Technical Relief (Technisches Hilfswerk, THW) than for other voluntary aid organisations — exacerbate this problem, leading to a heterogeneous and unreliable personnel contingent.

## 2. Structural imperatives for reinforcing personnel resilience

The conclusions drawn from this empirical diagnosis logically culminate in a set of irrefutable demands. These are aimed at stabilising the foundations of voluntary service and rendering them fit for the future.

1. **Creation of a uniform national legal status for responders:** The noted discrepancies in the legal status of responders from different organisations are no longer tenable. A national harmonisation of legislation concerning release from employment, continuation of salaries, insurance coverage, and social security is imperative. Irrespective of their organisational affiliation, every responder must be afforded the same legal and societal security. This is not merely a matter of fairness but a strategic necessity to ensure a plannable and dependable human resource pool.
2. **Systematic registration of dual roles and critical infrastructure affiliation:** The "critical infrastructure paradox" demands proactive management. It is essential to establish a system that systematically records the professional occupations of responders, with a particular focus on their function within the critical infrastructure entities. Only with this data can crisis management bodies conduct realistic personnel and resource planning and create necessary redundancies, rather than relying on "phantom forces" who will be unavailable when called upon.
3. **Implementation of support mechanisms for heavily burdened professional groups:** The commitment of individuals who are already subject to high levels of stress in their civilian professions (e.g., in the healthcare and nursing sectors) must be specifically fostered and protected. This can be achieved through the creation of incentive schemes for employers, tax advantages, guaranteed recovery periods following deployments, or flexible models of engagement that reduce the dual burden and sustain long-term motivation.
4. **Initiation of a recruitment and retention drive:** Considering demographic change, voluntary service must be modernised and actively promoted. This includes creating attractive framework conditions, ensuring the professional accreditation of skills acquired during service, providing state-of-the-art equipment, and fostering a deeply embedded culture of appreciation and recognition.

### 3. The technological vector: Digitalisation as a multiplier of efficiency

In parallel with the indispensable reinforcement of the personnel base, a second, technological pillar must be erected. Digitalisation offers the potential to act as a 'force multiplier' by scaling the reach and impact of scarce human expertise, optimising processes, and grounding decision-making in a broader base of information (Simmons et al. 2008).

Established applications in telemedicine already illustrate this principle. The concept of the "tele-emergency physician," whereby medical expertise is transmitted via data and voice channels to an incident scene to guide paramedics, is a successful example of decoupling expertise from physical presence. Research projects such as "TeleSAN" (funded by the German Federal Office for Civil Protection and Disaster Relief) are advancing this development by equipping first-aiders with mobile sensor technology (vital signs monitors, cameras, digital stethoscopes) (Uniklinik RWTH Aachen 2019). This enables a single expert in a command centre to supervise multiple teams on the ground, support diagnoses, and provide therapeutic instructions, which can significantly enhance the quality of care, e.g., during a mass casualty incident.

However, the efficacy of any digital strategy is inextricably linked to the resilience of its fundamental infrastructure. In a modern reimagining of Maslow's hierarchy of needs, power supply (battery life) and data connectivity (Wi-Fi/mobile networks) can be defined as the most basic, existential layers upon which all higher-level digital applications are built. As these very infrastructures are often the first to fail in a disaster, any digitalisation strategy that

is not founded upon a robust concept for self-sufficient energy and redundant communications is destined to fail. Investment in communication solutions that are independent of terrestrial infrastructure, such as satellite-based internet, is therefore not an option but a strategic necessity for building a digitally enabled and crisis-proof civil protection system.

### 4. The next stage of evolution: Data, predictive algorithms, and artificial intelligence

On the foundation of assured connectivity, a wide field opens up for transformative innovations in disaster medicine, based on the systematic use of data and AI.

A fundamental yet decisive step is the standardisation of data collection. The development of a national, standardised "Mass Casualty Incident (MCI) Register" represents a milestone in this regard. Through the uniform digital recording of injury patterns, interventions performed, and patient outcomes, a systematic, supra-regional analysis of major incidents would become possible for the first time. Such a register transforms isolated operational experiences into a collective, analysable body of knowledge, which can serve as the basis for the evidence-based refinement of guidelines, training concepts, and care protocols. The German Society for Disaster Medicine plans to introduce this MCI register in cooperation with many other professional societies for the year 2026.

Upon this data foundation, the next evolutionary step can be taken: the transition from reactive to predictive, decision-support systems. An example of this is the development of algorithms for a dynamic, anticipatory form of triage ("LIFE-Triage")

(Sigle et al. 2023). Traditional triage protocols assess a patient's condition statically at a single point in time. Dynamic algorithms, in contrast, use patient data to simulate the probable clinical trajectory over time. They can thus identify patients who may initially appear stable but who are at high risk of a subsequent, rapid deterioration ("decompensation"). This enables an anticipatory prioritisation, whereby scarce, highly specialised resources (e.g., surgical teams, intensive care transport capacity) can be proactively allocated to those patients with the greatest future need.

The most advanced, albeit still experimental, stage of development is the use of generative AI and Large Language Models (LLMs). Initial investigations demonstrate that such systems are capable, in principle, of correctly processing medical facts from case descriptions and deriving logically plausible triage decisions. At the same time, however, comparative studies with human experts reveal significant deficits in reliability and accuracy, particularly in the identification of the most critical patients. Therefore, while AI holds enormous potential as a future support and training tool, it cannot currently replace human experience, judgement, and ethical deliberation in safety-critical decision-making processes.

## Conclusion

### **An integrated strategy for the resilience of tomorrow**

The analysis of the current challenges facing the civil protection system leads to an unequivocal conclusion: mastering future crises requires an integrated and holistic strategy. The systemic problems of resource shortages, both in personnel and materiel,

and the paralysing effect of dual-role conflicts cannot be resolved by incremental improvements alone.

The solution lies in a dual-pronged approach that combines the best of both worlds — the human and the technological. A renewed social contract and bold political reforms are required to strengthen, secure, and value voluntary commitment. On the other hand, an accelerated yet strategically considered digital transformation is indispensable. The intelligent use of data to create a learning system, the implementation of telemedicine to scale expertise, and the application of predictive algorithms to optimise resource allocation are no longer future visions but necessary steps to secure national resilience. It is only through the synergistic combination of a reinforced human workforce and intelligent technological tools that it will be possible to effectively confront the complex disasters of the future.

### **Five strategic demands for a future-proof civil protection system**

Based on the foregoing analysis, the following five strategic demands are formulated as essential prerequisites for enhancing the systemic resilience of national civil protection:

1. **Establish a national statutory framework that guarantees legal and social parity for all volunteer responders**, irrespective of their organisational affiliation. This must include uniform regulations for release from employment, continuation of wages, insurance coverage, and long-term social security to create a reliable and equitably treated national resource.
2. **Implement a mandatory national register to systematically identify and manage the dual roles of emergency responders**, particularly those

employed within the critical infrastructure entities. This data is critical for realistic strategic planning and to mitigate the risk of systemic personnel conflicts during a large-scale crisis.

3. **Prioritise investment in resilient, redundant, and independent communication and energy infrastructures for civil protection units.** This must include the widespread deployment of satellite-based connectivity and off-grid power solutions to ensure the operational capability of digital systems even when terrestrial networks fail.
4. **Mandate the development and nationwide adoption of a standardised digital data collection system, such as a Mass Casualty Incident (MCI) Register.** This is essential to enable evidence-based analysis of incident management, refine clinical and operational guidelines, and transform the civil protection system into a continuously learning organisation.
5. **Launch a sustained national initiative to modernise volunteer recruitment and retention.** This initiative must incorporate flexible engagement models, the professional accreditation of skills acquired during service, and tangible support mechanisms for both volunteers and their employers to ensure the long-term viability of the voluntary service model.

## Author Contributions

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Gemini 2.5 Pro was used to develop an initial draft manuscript outline from the author's presentation slides that was used by the author to write the manuscript.

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