The Design and Implementation of ZIFA: A Central Information System for Civil Protection Vehicles and Equipment

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ABSTRACT

Civil protection authorities in Baden-Württemberg, Germany, have long relied on a fragmented landscape of databases and spreadsheets to manage their vehicle and equipment inventories. This heterogeneous data environment prevents cross-organizational analysis, impedes situational awareness during crises, and makes compliance reporting against the state's administrative regulation on disaster control services a labor-intensive manual process. Despite the operational significance of this challenge, no German state currently operates a centralized, IT-supported system for civil protection vehicle management. We present ZIFA (*Zentrales Informationssystem für Fahrzeuge und Ausstattungen des Katastrophenschutzes*), a GIS-enabled web application developed as a new module within the established *Elektronische Lagedarstellung für den Bevölkerungsschutz* (ELD-BS) ecosystem. ZIFA provides unified inventory management, map-based visualization, lifecycle management, cost tracking, and automated target/actual comparison across all administrative levels. The system was developed through a participatory co-design process involving the *Ministry of the Interior, Digitalisation and Local Government*, all four Regional Councils, and selected district authorities and relief organizations. We describe ZIFA's architecture using the five viewpoints of the *Reference Model of Open Distributed Processing* (RM-ODP) framework and contextualize its functionality through two analytical lenses: the crisis management cycle (prevention, preparedness, response, recovery) and the administrative hierarchy (state, regional, district, local). Implementation is complete and the system is currently undergoing its second testing phase, fully integrated within the ELD-BS environment. We discuss lessons learned from the participatory design process, current limitations, and the transferability of key design elements to other German states and international contexts.

Keywords

vehicle management, fleet management, equipment tracking, civil protection, crisis management tools, inventory management

INTRODUCTION

Effective crisis management depends not only on coordination and communication, but equally on a clear, real-time picture of available physical resources. Vehicles and equipment are among the most critical assets in civil protection: without accurate knowledge of what exists, where it is located, and whether it is operationally ready, even well-organized command structures cannot deploy resources efficiently. For civil protection authorities in

the state of Baden-Württemberg, Germany, this operational reality has long been complicated by fragmented, heterogeneous data landscapes: a patchwork of Microsoft Access databases and Excel spreadsheets, each maintained independently by individual organizations, often incompatible in format and impossible to aggregate across administrative boundaries. Across these distributed sources, approximately 1,270 vehicles and major equipment items are recorded—a volume that underscores both the operational significance of the fleet and the impracticality of managing it through unconnected, manually maintained tools.

ZIFA (Zentrales Informationssystem für Fahrzeuge und Ausstattungen des Katastrophenschutzes) is a new software module developed to address and fill this gap. Embedded within the established *Elektronische Lagedarstellung für den Bevölkerungsschutz* (ELD-BS) ecosystem, ZIFA provides a centralized, GIS-enabled web application for the unified management of civil protection vehicles and equipment across all administrative levels in Baden-Württemberg. It supports consistent data capture, cross-organizational analysis, lifecycle and scheduling management, cost tracking, and compliance reporting aligned with the Ministry of the Interior, Digitalisation and Local Government's administrative regulation on the strength and structure of the disaster control service (VwV KatSD; (Ministerium für Inneres, Digitalisierung und Migration Baden-Württemberg 2019)).

This paper presents ZIFA as a work in progress. The authors describe the operational context and motivation, detail the integration within the ELD family, map ZIFA's functionality onto the civil protection crisis management cycle, and illustrate how the system serves the diverse needs of actors across the administrative hierarchy, from the Ministry of the Interior to individual relief organizations. Beyond its practical contribution, the paper offers transferable design knowledge by documenting the participatory development process, the mapping of regulatory requirements to system functionality, and the lessons learned from co-designing an information system within a complex multi-level administrative setting.

The remainder of this paper is structured as follows. Section 2 reviews related work in resource management for civil protection at the international, federal, and state levels. Section 3 provides the necessary background on the ELD-BS ecosystem, the current state of fleet management and the regulatory framework (VwV KatSD). Section 4 presents ZIFA's system design through the five viewpoints of the RM-ODP framework. Section 5 contextualizes ZIFA's functionality along two analytical dimensions: the crisis management cycle and the administrative hierarchy. Section 6 reports on the current implementation status. Section 7 discusses lessons learned, limitations, and transferability. Section 8 concludes and outlines future work.

RELATED WORK

To situate ZIFA within the broader landscape of resource management in civil protection, we review existing systems and approaches at three levels: international frameworks (Section 2.1), German federal-level systems (Section 2.2), and state-level approaches across the German federal states (Section 2.3). This structured review serves to identify the specific gap that ZIFA addresses and to delineate the boundaries between operational coordination tools and strategic inventory management systems.

International Resource Management Frameworks

FEMA/NIMS Resource Management (USA)

In the United States, the National Incident Management System (NIMS) provides a comprehensive framework for resource management across all government levels, establishing standardized processes and common terminology for inventorying, typing, mobilization, deployment, and tracking of resources (Federal Emergency Management Agency 2025a; Federal Emergency Management Agency 2018; Federal Emergency Management Agency 2024). Within this framework, the Resource Typing Library Tool (RTLT) catalogues national resource typing definitions, while the Resource Inventory System (RIS) offers a centralized, cloud-hosted inventory solution enabling organizations to manage resources consistently with NIMS definitions across jurisdictions (Federal Emergency Management Agency 2025b; Federal Emergency Management Agency 2025c).

RIS represents the closest international analogue to ZIFA; however, the two systems differ fundamentally in their administrative context. RIS is designed for voluntary adoption across the decentralized US federal structure, whereas ZIFA is tightly coupled to a specific binding state regulation, the VwV KatSD. This regulatory integration, combined with ZIFA's GIS-enabled capabilities and embedding within an established state IT ecosystem, represents a degree of administrative specificity that general-purpose inventory tools are not designed to provide.

EU Civil Protection Mechanism / CECIS

At the European level, the EU Civil Protection Mechanism coordinates disaster response across Member States through the Emergency Response Coordination Centre (ERCC), which operates 24/7 and manages requests for international assistance (European Commission 2026a). Its technical backbone, the Common Emergency Communication and Information System (CECIS), is a web-based alert and notification platform enabling real-time information exchange between national authorities (Elbez and Alevantis 2004). Complementing this, the European Civil Protection Pool (ECPP) maintains a register of pre-committed, certified response capacities, such as specialist teams and equipment, available for rapid international deployment (European Commission 2026c).

While the EU Civil Protection Mechanism represents a sophisticated framework for cross-border resource coordination, its scope is fundamentally different from ZIFA's (European Commission 2026b). CECIS and the ECPP are designed for operational exchange between states during active disaster response, not for strategic inventory management within a single administrative unit. ZIFA, by contrast, addresses the preparedness phase at the sub-national level, providing regulation-compliant fleet management within Baden-Württemberg rather than coordinating international deployments.

German Federal-Level Systems

At the federal level, the Joint Reporting and Situation Centre (*Gemeinsames Melde- und Lagezentrum*, GMLZ), operated by the Federal Office of Civil Protection and Disaster Assistance (*Bundesamt für Bevölkerungsschutz und Katastrophenhilfe*, BBK) since 2002, serves as the central coordination point for nationwide information and resource management. It maintains situational awareness across civil protection-relevant events, coordinates German assistance contributions in international disaster response as Germany's national contact point for EU CECIS, and brokers scarce resources upon request from the states (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe 2026a; Bundesamt für Bevölkerungsschutz und Katastrophenhilfe 2026b). However, the GMLZ is an operational coordination body, not an inventory system; it responds to concrete requests rather than maintaining a strategic resource registry.

An earlier attempt at systematic information management was the German Emergency Preparedness Information System (deNIS), developed following the September 11 attacks and the 2002 Elbe floods as part of the federal *New Strategy for Civil Protection*. Its public-facing component (deNIS I) and the restricted decision-maker platform (deNIS IIplus) were both decommissioned by 2015, leaving no successor system at the federal level.

Regarding physical assets, the BBK is responsible for procuring and equipping a federal fleet of civil protection vehicles, targeting 5,421 vehicles under the 2008 supplementary equipment concept. These vehicles are transferred to the individual states for further distribution (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe 2026c).

Despite the scale of this fleet, there is no central IT platform for nationwide inventory tracking; management is based on decentralized lists and handover protocols, and location data are no longer publicly disclosed for security reasons. This finding is significant: even at the federal level, a centralized IT-supported fleet inventory system is absent.

German State-Level Approaches

Since civil protection in Germany is a state-level responsibility under Article 70 of the Basic Law, each federal state organizes the management of its civil protection vehicles and equipment independently. Research across all states reveals no comparable centralized IT system for strategic fleet inventory management, with fragmentation being the consistent pattern.

Bavaria presents the most documented case of this fragmentation. The state operates a heterogeneous landscape of multiple parallel systems including EPSKweb, GeoKAT, EMS, BMS, and others, supplemented by additional tools used by relief organizations that are not integrated into municipal or state IT infrastructure. The state's own civil protection concept *Katastrophenschutz Bayern 2025* explicitly acknowledges this as an unresolved challenge, describing it as "a major challenge to connect these systems from bottom to top" (Bayerisches Staatsministerium des Innern, für Sport und Integration 2023). Vehicle inventory data is published as a static document rather than managed through a dynamic IT system (Bayerisches Staatsministerium des Innern, für Sport und Integration 2025).

North Rhine-Westphalia is developing VIDaL, a networked situation platform that includes resource management capabilities for identifying available civil protection units statewide during crises (T-Systems International GmbH 2023). As the most comparable state-level initiative, VIDaL is nevertheless broader in scope, focusing on overall situational awareness rather than dedicated fleet inventory management, and does not support comparisons against a binding administrative regulation. As of 2025, the system remains in pilot operation.

Lower Saxony publishes its civil protection equipment documentation as static PDF downloads, with no dynamic IT-based inventory system in evidence (Niedersächsisches Landesamt für Brand- und Katastrophenschutz 2023; Niedersächsisches Landesamt für Brand- und Katastrophenschutz 2025). This document-based approach is broadly representative of common practice across German states, where vehicle and equipment management typically relies on Excel spreadsheets, PDF catalogues, and isolated proprietary solutions at the district or organization level.

The review of existing systems across international, federal, and state levels reveals a consistent finding: no centralized, IT-supported system for strategic civil protection fleet management exists at the sub-national level in Germany. International frameworks such as NIMS/RIS and the EU Civil Protection Mechanism operate at a different administrative scale and lack binding coupling to state-level regulations. At both federal and state levels, fragmented manual approaches remain the norm.

ZIFA differs from these approaches in three key respects: unlike Bavaria's fragmented parallel systems and Lower Saxony's static document-based approach, it provides a single dynamic data source accessible across all administrative levels; unlike NRW's VIDaL, it is dedicated to fleet inventory management rather than general situational awareness; and unlike all three, it is directly coupled to a binding administrative regulation (VwV KatSD), enabling automated target/actual compliance reporting. ZIFA thus directly addresses this gap as the first centralized, web-based, regulation-compliant fleet management system within a German state, with transfer potential for other states facing comparable challenges.

BACKGROUND

ELD-BS Family

The *Elektronische Lagedarstellung für den Bevölkerungsschutz* (ELD-BS) is a modular suite of crisis management software tools developed for the German federal state of Baden-Württemberg and its civil protection authorities (Hellmund, Schenk, Moßgraber, et al. 2022). Built on Fraunhofer IOSB's WebGenesis® platform and continuously developed since 2009, ELD-BS is widely used across all administrative levels, from municipalities and counties to regional councils and state ministries. The platform is designed to support both parallel and serial incident management across a wide spectrum of event types, including floods, wildfires, earthquakes, nuclear accidents, and unforeseen crises such as the 2015 refugee situation and the COVID-19 pandemic.

The ELD family currently comprises the following components:

- ELD-BS, the core situation dashboard,
- *Krisenobjektdatenbank* (KODB), a crisis object database (Hellmund, Schenk, and Schaaf 2025),
- ELD-DOK, a document exchange portal for situation reports, and
- ZEUS-BS, a tool for planning and managing evacuations and accommodations for civil protection (Hellmund, Moßgraber, et al. 2021).

A key architectural principle of ELD-BS is its hierarchical diary structure: each administrative unit maintains its own diary, with entries mirrored upward into aggregation diaries that allow superior levels to monitor the situation without being overwhelmed by individual updates. Access control is per-report and role-based rather than per-individual, with time-stamped role assignments enabling traceability and deputyship. These same principles of transparency, auditability, and hierarchical information flow carry through into the design of ZIFA.

ZIFA extends the ELD-BS ecosystem with the missing vehicle and equipment dimension, benefiting from the existing user management, GIS services, and hierarchical access model.

Fleet and Equipment Management

While ELD-BS includes a basic component serving as a shared reference database for vehicle types and associated documents, this falls well short of the operational needs of disaster control authorities responsible for managing state-provided assets. Currently, organizations rely on a heterogeneous mix of Microsoft Access databases and Excel spreadsheets to track vehicle inventories, equipment assignments, maintenance schedules, and procurement costs. These tools are maintained independently by each organization, use inconsistent data formats, and cannot be aggregated across administrative or organizational boundaries.

The practical consequences of this fragmentation are significant. During a crisis, command staff at regional or state level cannot quickly answer fundamental questions: *How many Type-X vehicles are currently operational in a given*

region? What equipment is assigned to which vehicle? In the preparedness phase, the lack of cross-organizational data makes it impossible to conduct statewide analyses for procurement planning or compliance reporting under VwV KatSD. And because existing tools offer no structured audit trail, demonstrating regulatory compliance or reconstructing resource deployment after an incident is laborious and error-prone.

ZIFA delivers practical, operational value. In the preparedness phase, answering a question such as *"Which districts currently have fewer vehicles than prescribed by VwV KatSD?"* requires manual data collection and aggregation. With ZIFA, such queries can be answered directly from the system in real time. Similarly, identifying vehicles approaching end-of-life for timely procurement planning, or verifying compliance across the entire state, becomes a routine operation rather than a periodic, resource-intensive exercise. During an active crisis, command staff currently lack an integrated spatial overview of available assets; ZIFA's GIS-enabled map view provides immediate visibility of vehicle locations and types, supporting rapid identification of the nearest suitable resources for cross-district deployment.

ZIFA is designed to resolve these structural deficiencies by providing a single, authoritative, and interoperable system for fleet and equipment management while also integrating seamlessly into the existing ELD-BS environment and respecting the established governance structures of civil protection in Baden-Württemberg.

Regulatory Foundation: The VwV KatSD

In Germany, civil protection (*Bevölkerungsschutz*) is the overarching term for all tasks and measures aimed at protecting the population from disasters, crises, and the consequences of armed conflict (Karutz et al. 2021). It comprises two constitutionally distinct pillars: civil defense (*Zivilschutz*), which addresses the protection of the civilian population in the event of war or armed conflict and falls under the exclusive legislative competence of the federal government (Art. 73 para. 1 no. 1 GG), and disaster protection (*Katastrophenschutz*), which covers peacetime disaster management and is the responsibility of the individual federal states (*Länder*) under Art. 70 GG (Bundesministerium des Innern und für Heimat 2025). This constitutional division results in 16 distinct state-level legislative and organizational frameworks for disaster protection. Despite this separation of competencies, the two pillars are operationally linked through an integrated assistance system (*Integriertes Hilfeleistungssystem*): resources provided by the federal government for civil defense can also be used by the states for disaster protection, and conversely, state-level organizations stand ready to support the federal government in a defense scenario—a mutual resource sharing arrangement that directly affects the vehicle fleet managed by ZIFA, which includes both federal-owned and state-owned vehicles. In Baden-Württemberg, the legal foundation for disaster protection is the *LKatSG* (*Landeskatastrophenschutzgesetz*). On this basis, the Ministry of the Interior, Digitalisation and Local Government issued the *VwV KatSD* (*Verwaltungsvorschrift über die Stärke und Gliederung des Katastrophenschutzdienstes*), an administrative regulation specifying the required number, structure, and equipment of disaster control service units across the state (Ministerium für Inneres, Digitalisierung und Migration Baden-Württemberg 2019). The VwV KatSD serves as the binding regulatory framework against which ZIFA's compliance reporting is designed.

Together, the VwV KatSD and the LKatSG define a set of regulatory obligations that directly translate into concrete tasks for any system managing civil protection vehicles and equipment. The VwV KatSD prescribes the target composition of disaster control units, specifies which assets are to be provided by relief organizations, the state, and the federal government, designates units for cross-jurisdictional deployment, and details the required vehicle and equipment assignments per service branch and district in its appendices. The LKatSG complements this by assigning participating organizations the responsibility to ensure permanent operational readiness of their units (Land Baden-Württemberg 2025). Table 1 summarizes the vehicle management tasks that ZIFA must fulfil to satisfy the regulatory requirements. Additional operational requirements—including lifecycle management, scheduling, cost tracking, document storage, and audit trails—are not prescribed by the regulation but emerged from the participatory co-design process and are detailed in Section 4.1.

The Crisis Management Cycle

The crisis management cycle is a well-established conceptual framework for organizing civil protection activities. It structures the work of disaster control authorities not as a series of reactive responses to individual events, but as a continuous, circular process of planning, readiness maintenance, operational deployment, and post-incident learning. While different models exist across national and institutional contexts, the cycle is most commonly divided into four phases: Prevention and Mitigation, Preparedness, Response, and Recovery (Coppola 2006; Karutz et al. 2021).

Prevention and Mitigation encompass measures aimed at reducing the likelihood of disasters occurring and limiting their potential impact before any specific threat materializes. *Preparedness* covers the ongoing activities that ensure authorities, organizations, and resources are in a state of readiness to respond effectively when needed. This

Table 1. Vehicle management tasks derived from VwV KatSD and LKatSG.

Task	Description	VwV Ref.
T1	Maintain central inventory of civil protection vehicles across all districts	§1.1, App.
T2	Track vehicle assignments to service branches and units	§1.1
T3	Record vehicle characteristics (type, condition, age, funding source)	§1.5
T4	Compare actual inventory against target inventory per VwV KatSD	App. 1–8
T5	Provide spatial overview of vehicle distribution	§1.6
T6	Enable reporting on inventory status across administrative levels	§9 LKatSG
T7	Support cross-district resource identification	§1.6
T8	Differentiate federal vs. state vs. organization-owned assets	§1.5

also includes training, exercising, planning, and the maintenance of equipment and personnel. *Response* is the operational phase in which resources are mobilized and deployed to manage an active incident, requiring rapid situational awareness and coordinated decision-making. *Recovery* addresses the transition back to normality after an incident, including the restoration of damaged infrastructure, the replenishment of depleted resources, financial reconciliation, and the documentation and evaluation of the response for organizational learning.

Critically, the four phases are not strictly sequential but overlap and inform one another continuously. Lessons learned during recovery feed directly into prevention and preparedness planning; preparedness activities shape the speed and effectiveness of response. This cyclical nature means that information systems supporting civil protection must be useful not just during acute incidents, but across the full spectrum of routine and crisis operations. ZIFA's functionality is designed with this breadth in mind, ensuring that fleet and equipment data is not merely a static administrative record but an active contribution to operational effectiveness across all four phases.

SYSTEM DESIGN

ZIFA's system design is presented through the five viewpoints of the *Reference Model of Open Distributed Processing* (RM-ODP) (ISO/IEC 1998; Kilov et al. 2013), an established framework for describing complex distributed information systems. The enterprise viewpoint captures stakeholder concerns and requirements; the information viewpoint describes the underlying data model; the computational viewpoint defines functional decomposition and use cases; the engineering viewpoint addresses system integration and distribution; and the technology viewpoint specifies the concrete implementation platform.

Enterprise Viewpoint: Stakeholders and Requirements

ZIFA has been developed following a participatory co-design approach that has proven effective in previous ELD-BS modules. For the participatory design (PD) Spinuzzi (2005) identifies three methodological stages: (1) initial exploration of work practices, (2) discovery processes in which researchers and participants jointly analyze findings and develop shared understanding, and (3) iterative prototyping where design artifacts are collaboratively refined. ZIFA's development process comprised three phases that map onto this framework as follows.

In the **first phase** (corresponding to Spinuzzi's initial exploration), the development team, in cooperation with the Ministry of the Interior, Digitalisation and Local Government, analyzed the existing landscape of fleet management practices across administrative levels. This included a review of the heterogeneous data sources in use (primarily Microsoft Access databases and Excel spreadsheets) maintained independently by individual organizations as well as the regulatory framework (VwV KatSD with its appendices) and the standardized form for reporting unit readiness. The goal of this phase was to develop a thorough understanding of the problem domain and the operational context before engaging stakeholders directly.

In the **second phase** (corresponding to Spinuzzi's discovery processes), structured workshops were conducted with representatives from all administrative levels, including the Ministry of the Interior, all four Regional Councils, and selected district authorities. In these workshops, participants and the development team jointly analyzed the findings from the initial exploration, identified core requirements through direct stakeholder dialogue, and developed a shared understanding of the system's functional scope.

The **third phase** (corresponding to Spinuzzi's prototyping stage) was organized in two sub-phases. In the first sub-phase, a detailed technical concept document was developed from the workshop outcomes and subjected to formal review cycles with all stakeholder groups. This concept document, which included mockups of the envisioned user interface, served as a paper prototype and a shared boundary object between developers and domain

experts. Written feedback from Regional Councils and district authorities led to iterative refinement. In the second sub-phase, the concept was translated into a working implementation. Stakeholders received continuous access to test versions throughout development, providing regular feedback that informed ongoing adjustments. Testing was organized in two stages: first as a standalone ZIFA module for core service validation and user acceptance testing with the stakeholder groups already involved in the earlier phases, then as an integrated component within the full ELD-BS environment, progressively extending access to additional user groups including district-level disaster control authorities and relief organizations. This broader testing covered end-to-end workflow testing, cross-module data consistency, and validation of the hierarchical access control model across all administrative levels and user groups.

The following requirements were derived from this process (Table 2).

Table 2. Requirements derived from the participatory co-design process.

Req	Description
R1	Central registration of vehicles and equipment with VwV-compliant attributes
R2	Assignment to service branches, units, and districts
R3	Target/actual comparison against VwV KatSD target inventory
R4	Map-based visualization of vehicle locations and distribution
R5	Statistical reporting and KPIs across all administrative levels
R6	Role-based access per administrative hierarchy
R7	Support identification of available resources for cross-district deployments
R8	Differentiation of asset ownership (federal, state, organization)
R9	Lifecycle management including decommissioning and reactivation
R10	Schedule management for inspections and maintenance
R11	Cost and invoice tracking
R12	Document storage (PDFs, images) per vehicle

Information Viewpoint: Data Model

ZIFA's information model is structured around the central entity *vehicle*, characterized by a set of VwV KatSD-compliant attributes including vehicle type, operational status, funding source (federal, state, or organization-owned), and organizational assignment. Each vehicle is linked to a hierarchical organizational structure reflecting the administrative levels defined in VwV KatSD: service branch, tactical unit, district, and regional council. The data model supports a target/actual *(SOLL/IST)* comparison by maintaining both the prescribed inventory per VwV KatSD appendices and the actual registered fleet.

Lifecycle data encompasses registration, commissioning, decommissioning, and reactivation states, as well as scheduled events such as inspections and maintenance intervals. Financial records, including procurement costs and invoices, are associated with individual vehicles. Document attachments (PDFs, images). Figure 1 illustrates the core entities and their relationships.

Computational Viewpoint: Functional Decomposition

ZIFA's functionality is decomposed into six core use cases that together address the full range of operational requirements (Table 3).

Table 3. ZIFA's core use cases.

UC	Functionality	Description
UC1	Vehicle Registration	Central capture of vehicles with hierarchical data entry
UC2	Unit Assignment	Mapping to VwV KatSD structure (service branches, tactical units)
UC3	Map View	GIS-based spatial overview of fleet distribution
UC4	Target/Actual Comparison	Actual vs. target inventory per VwV KatSD
UC5	Reporting	Statistical evaluations, KPIs, export functions
UC6	Access Control	Hierarchical role-based permissions

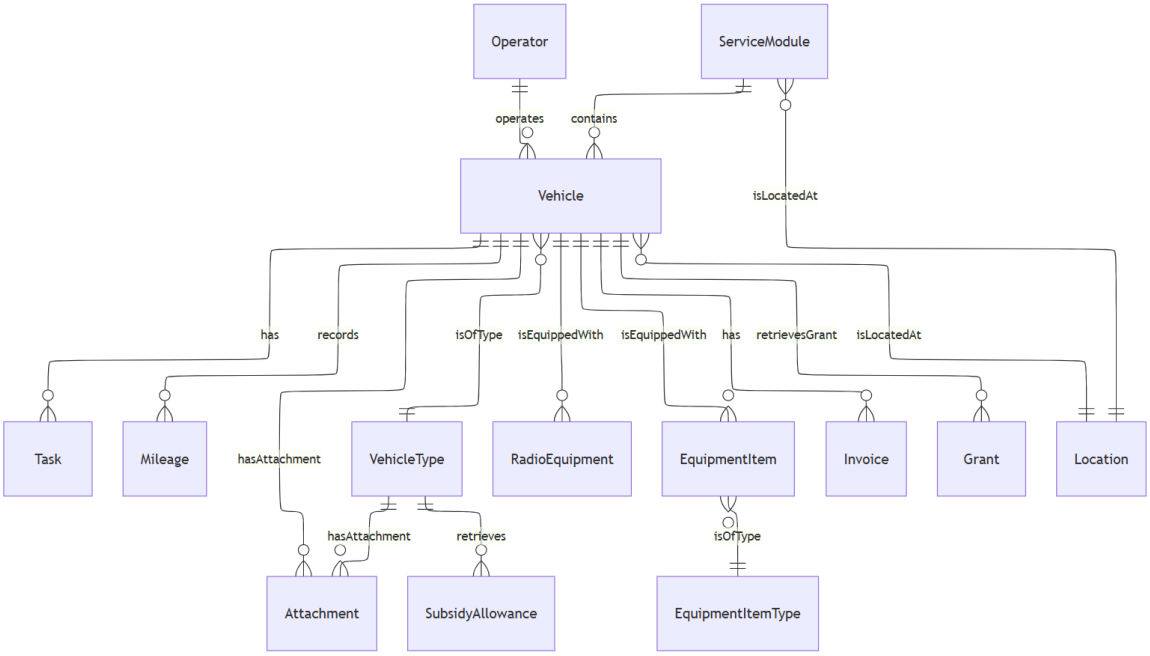

Figure 1. Core entities and relationships of ZIFA's data model.

Engineering Viewpoint: Platform Integration

ZIFA is not a standalone system but a module within the ELD-BS ecosystem, accessible alongside ELD-BS, ZEUS, KODB, and ELD-DOK through a shared entry point. All modules share a centralized user management infrastructure: user accounts are created once and apply across the entire suite, with role-based access control governing data visibility according to the administrative hierarchy. GIS services, provided by the *Landesamt für Geoinformation und Landentwicklung Baden-Württemberg* (LGL-BW), are likewise shared across modules. The common platform basis ensures a consistent user interface across all ELD modules, which reduces training effort and supports adoption among users already familiar with other components of the suite. Currently, ZIFA operates as a self-contained component within ELD-BS, with no direct data exchange between modules. Deeper integration—for example, linking ZIFA vehicle availability data with ZEUS evacuation planning—is envisioned as future work (Section 8).

Technology Viewpoint: Implementation Stack

ZIFA is built on WebGenesis®, an information management and decision support system developed by Fraunhofer IOSB that provides the shared technological foundation for the entire ELD-BS ecosystem. Key platform capabilities leveraged by ZIFA include native GIS integration through open OGC protocols, workflow support for hierarchical processes, and integrated document management. ZIFA is implemented as a fully web-based application, accessible through a standard browser without local installation—a deliberate design choice to ensure low-barrier access for volunteer-based relief organizations that typically lack dedicated IT infrastructure. For map-based visualization, ZIFA integrates Web Map Services (WMS) provided by LGL-BW, ensuring consistency with other government GIS applications.

ZIFA IN CONTEXT

The Crisis Management Cycle

Prevention and Mitigation

In the prevention phase, ZIFA supports the long-term management and analysis of the civil protection vehicle fleet at the statewide level. Accurate, centralized inventory data enables planners at the Ministry of the Interior and Regional Councils to identify gaps in regional coverage, assess the age profile and condition of the fleet, and make evidence-based procurement decisions. Cost records and invoice data allow trends in maintenance expenditure to be tracked over time, supporting budget planning and the early identification of assets approaching end-of-life.

Critically, ZIFA's reporting module generates structured compliance reports aligned with VwV KatSD, enabling the Ministry of the Interior to verify that organizational strength and equipment standards are met across all subordinate units, without requiring manual aggregation of data from dozens of separate organizations. This shifts compliance verification from an episodic, labor-intensive process to a continuous, automated one.

Preparedness

The preparedness phase is where ZIFA's day-to-day operational value is most evident. Scheduling management allows organizations to plan and track inspection intervals and maintenance windows for each vehicle, ensuring that assets are kept in a known, documented state of readiness. Availability status is maintained in real time, providing an accurate picture of deployable capacity at any given moment.

For training and exercise planning, ZIFA's GIS-enabled overview allows planners to identify which assets and units are available in a given region and when. This supports realistic scenario planning and helps ensure that exercises reflect actual rather than assumed resource availability. At the regional level, users can use cross-district aggregations to identify temporary capacity shortfalls (for example, when multiple vehicles in the same district enter the maintenance cycle simultaneously) and coordinate compensatory measures in advance.

Response

During an active crisis event, the speed and accuracy of resource information are critical. ZIFA's integration with the ELD-BS situation dashboard means that command staff do not need to switch between systems or make telephone inquiries to determine what assets are available. The GIS-enabled map view provides an immediate spatial overview of vehicle locations and operational status, allowing deployment decisions to be made on the basis of current, reliable data rather than outdated spreadsheets or informal knowledge.

Role-based access control ensures that each actor sees the information relevant to their operational level: field coordinators at a district see their own unit's assets in detail, while a regional council's crisis team sees an aggregated regional picture, and the Ministry of the Interior can access a statewide overview. This mirrors the hierarchical visibility model established in ELD-BS and avoids information overload at higher command levels while preserving operational detail where it is needed.

Recovery

After an incident, ZIFA supports the recovery and documentation phase in several ways. Vehicle and equipment records can be updated to reflect damage or wear sustained during deployment, feeding directly into repair and replacement planning. Cost and invoice data linked to the event period supports post-incident financial reconciliation and, where applicable, reimbursement processes.

The Administrative Hierarchy

Civil protection in Baden-Württemberg operates across a clearly defined hierarchy of administrative levels, each with distinct responsibilities and information needs. ZIFA is designed to serve all levels of this hierarchy through a single integrated system, with role-based access control and differentiated data views ensuring that each actor interacts with the system in a way appropriate to their organizational position (Table 4).

Table 4. ZIFA usage across administrative levels.

Level	Organization	Primary ZIFA Use
State	Ministry of the Interior	Strategic oversight, compliance reporting, vehicle type management
Regional	4 Regional Councils	Regional coordination, cross-district visibility, user administration
District	44 Urban/Rural Districts	Operational fleet management, lifecycle management, data ownership
Local	Relief Organizations	Asset stewardship, limited data entry for assigned vehicles

Ministry of the Interior: Strategic Oversight

At the apex of the hierarchy, the Ministry of the Interior requires a high-level, aggregated view of the statewide civil protection vehicle fleet. The Ministry is responsible for the initial registration of vehicles in the system and the definition of vehicle types, establishing the master data foundation on which all subordinate levels operate. ZIFA's reporting module generates structured outputs that map directly onto VwV KatSD organizational and equipment categories, enabling the Ministry to verify compliance, identify systemic gaps, and inform strategic decisions about

procurement, regional resource distribution, and policy. The Ministry also holds overall responsibility for user administration governance, setting the framework within which Regional Councils manage access for subordinate units.

Regional Councils: Regional Coordination

The four Regional Councils (Freiburg, Tübingen, Stuttgart, Karlsruhe) in Baden-Württemberg occupy a critical coordination layer between state policy and district-level operations. In ZIFA, they are responsible for the assignment of vehicles to districts and provide regional oversight across all municipalities within their region. They can view aggregated fleet and availability data, identify cross-district patterns (such as clustered maintenance periods that could reduce regional capacity), and coordinate the deployment of assets across district boundaries during incidents. They also manage user administration for their subordinate units, including relief organizations operating within their regional boundaries.

Municipalities: Operational Management

Cities and counties are the primary data owners in ZIFA. Their staff is responsible for maintaining accurate, up-to-date records of all vehicles and equipment assigned to their organizational unit, including lifecycle states, scheduled inspections, maintenance history, and associated documents. Districts hold the authority over decommissioning and reactivation decisions for vehicles within their jurisdiction. Cost and invoice records are entered at this level. ZIFA's interface is designed to support efficient data entry workflows for administrative staff who may interact with the system regularly but are not specialist IT users.

Relief Organizations: Asset Stewardship

Non-governmental relief organizations (including DRK, DLRG, MHD, JUH, ASB, Bergwacht, and BRH) are allocated state-provided vehicles and equipment and are therefore included in ZIFA as data-entry users for their own assets. Their data entry responsibilities are limited to operational information such as mileage, inspection and maintenance schedules, and equipment status. Their access is scoped strictly to their own organizational records; they cannot view data from other organizations. This ensures that the statewide dataset is built from the distributed knowledge of the organizations closest to the assets, while maintaining appropriate data boundaries. User accounts for relief organizations are created and managed by the responsible municipality authority.

IMPLEMENTATION STATUS

As of the time of writing, ZIFA's implementation is complete and the system has entered its second testing phase, now fully integrated within the ELD-BS environment. Test users from all administrative levels are actively involved, including representatives from Regional Councils, district authorities, and relief organizations. The rollout to all stakeholders is planned upon successful completion of this testing phase. Importantly, ZIFA has not yet been deployed under actual crisis conditions, and its performance in a real operational scenario remains to be validated. Figures 2 and 3 illustrate the map overview and a vehicle detail view, respectively.

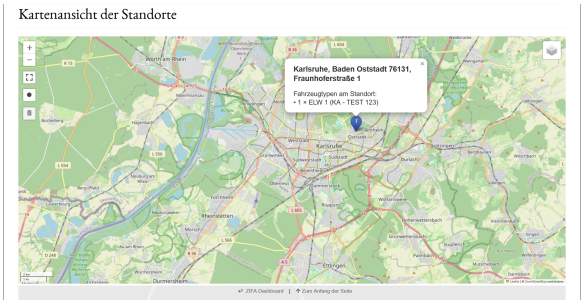

Figure 2. Map overview of the vehicles.

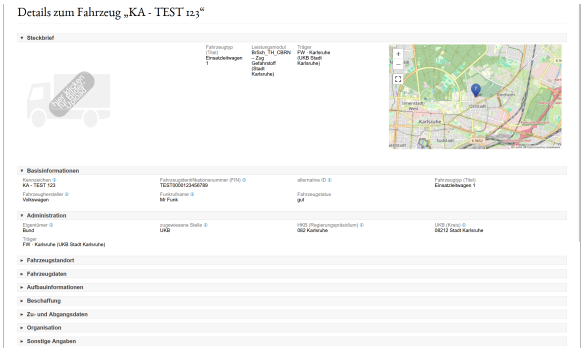

Figure 3. Detail page describing a vehicle.

DISCUSSION

Lessons from Participatory Design

The intensive involvement of end users throughout the development process yielded important insights that were not fully anticipated in the initial concept work. Early and continuous stakeholder dialogue proved essential not

only for identifying critical use cases and assessing development progress, but also for uncovering areas where the system design needed to accommodate more variability than originally envisioned. Two themes emerged as particularly significant.

First, the VwV KatSD defines a structural framework that deliberately allows room for interpretation. During the participatory process, it became apparent that the concrete implementation of these interpretive margins for example, in the assignment of vehicles to tactical units or in handling organizational special cases such as temporary assignments and shared usage between organizations varies considerably across districts and regions. A rigid, one-size-fits-all data model would not have reflected this legitimate variance and would likely have been rejected by parts of the user base. The data model therefore had to be designed flexibly enough to accommodate regional differences without compromising the regulatory compliance framework that motivates ZIFA's core functionality. Without direct dialogue with practitioners across all administrative levels, these variations would likely have surfaced only after deployment, at much greater cost. This finding aligns with a core tenet of participatory design: that tacit, practice-based knowledge held by domain practitioners cannot be fully captured through document analysis or formal specifications alone, but must be elicited through sustained collaborative engagement in which participants act as co-designers rather than mere informants (Spinuzzi 2005).

Second, the ongoing dialogue with users revealed additional use cases that had not been considered in the original requirements analysis. The iterative nature of the development process allowed functionality to be expanded incrementally in response to these discoveries. Notable examples include edge cases in lifecycle management, such as temporary decommissioning of vehicles and inter-district transfers, which required additional data handling and workflow support beyond the initial specification.

Limitations

Several limitations must be acknowledged. The transition from testing to productive operation marks the most immediate milestone and will be accompanied by a phased onboarding process designed to gradually introduce all relief organizations to the system. Long-term user acceptance across a diverse and decentralized user base cannot be assumed and will need to be actively supported through training, documentation, and responsive feedback channels. Furthermore, the quality of the centralized dataset depends fundamentally on the input discipline of distributed data-entry users across dozens of organizations, necessitating the establishment of clear data quality processes and governance structures. The migration of legacy data from existing Microsoft Access databases and Excel spreadsheets into ZIFA remains a significant practical challenge, both in terms of data cleaning and format harmonization. From a methodological perspective, the participatory design process involved a limited number of representative stakeholders rather than the full user base, and the iterative refinement was driven primarily by complementary additions rather than conflicting requirements—a pattern that may not generalize to more heterogeneous or contested organizational settings. Finally, ZIFA's performance under actual crisis conditions has not yet been validated, and its operational effectiveness in a real emergency scenario remains an open question.

Transferability

Although ZIFA was developed against Baden-Württemberg-specific regulations, key design elements are transferable to other German states and, in principle, to international contexts. The hierarchical access control model and role-based data visibility concept apply directly, since all German states and many international civil protection systems organize responsibilities through comparable multi-level administrative hierarchies, even where the specific allocation of competencies differs. The core data model (vehicles linked to organizational units, lifecycle states, scheduling, and cost tracking) addresses functionally equivalent requirements that are not specific to any single regulatory framework. However, the target/actual comparison mechanism and compliance reporting attributes are tailored to the VwV KatSD and would require adjustment to reflect the target jurisdiction's own regulations and inventory definitions. Beyond the German context, the participatory co-design methodology and the modular integration approach within an existing crisis management ecosystem offer transferable lessons for any jurisdiction seeking to centralize fragmented fleet data.

A key technical prerequisite for cross-state or cross-border data exchange, however, has not yet been addressed. As noted in Section 4.5, ZIFA currently does not expose public APIs or standardized data exchange interfaces. While this is sufficient for its present scope as a state-internal system, any future scenario involving cross-state resource coordination, for example, during large-scale disasters requiring mutual aid between federal states, would require the development of interoperable interfaces and agreed-upon data exchange formats. The underlying technology stack, built on open standards (OGC for geospatial services), provides a favorable foundation for such an effort, but the concrete definition and standardization of exchange interfaces remains an open task for future work.

As shown in Section 2.3, no German state currently operates a comparable system, and international frameworks such as FEMA/NIMS and CECIS (Section 2.1) focus on operational coordination rather than strategic inventory management. ZIFA can therefore serve as a reference implementation for both national and international efforts.

CONCLUSION AND FUTURE WORK

ZIFA addresses a genuine and operationally significant gap in Baden-Württemberg's civil protection infrastructure. By embedding a centralized, GIS-enabled fleet management module within the established ELD-BS ecosystem, it transforms vehicle and equipment data from a siloed administrative burden into an integrated operational resource—serving distinct purposes across all phases of the crisis management cycle and all levels of the administrative hierarchy, from the Ministry of the Interior to individual relief organizations. To the best of our knowledge, ZIFA represents the first centralized, IT-supported fleet management system for civil protection at the state level in Germany.

Currently, aside from the central entry point and shared account and access rights management, ZIFA operates as a standalone component within the ELD-BS software suite. This opens the door for deeper integration with other ELD-BS modules in future work. For example, an extensive evacuation could be managed by ZEUS while ZIFA provides information on available emergency vehicles. Furthermore, the centralized and harmonized data collection forms the basis for cross-state data exchange during rescue operations—within Germany or with foreign countries. Realizing this potential will require transferring interfaces and data models into a standardization process. Finally, validating ZIFA's performance under real crisis conditions remains a key objective for future work and will be an important step toward demonstrating the system's full operational value.

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REFERENCES

Bayerisches Staatsministerium des Innern, für Sport und Integration (2023). *Konzept Katastrophenschutz Bayern 2025*. Bayerisches Staatsministerium des Innern, für Sport und Integration.

Bayerisches Staatsministerium des Innern, für Sport und Integration (Dec. 2025). *Fahrzeugbestand in der Ergänzung des Katastrophenschutzes durch den Bund: Soll- und Ist-Zahlen im Freistaat Bayern*. Bayerisches Staatsministerium des Innern, für Sport und Integration.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2026a). *Gemeinsames Melde- und Lagezentrum (GMLZ)*. URL: https://www.bbk.bund.de/DE/Themen/GMLZ/gmlz_node.html.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2026b). *Ressourcenmanagement – Gemeinsames Melde- und Lagezentrum*. URL: https://www.bbk.bund.de/DE/Themen/GMLZ/Ressourcenmanagement/ressourcenmanagement_node.html.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2026c). *Zivilschutzfahrzeuge – Ergänzende Ausstattung*. URL: https://www.bbk.bund.de/DE/Themen/Ergaenzende-Ausstattung/Zivilschutzfahrzeuge/zivilschutzfahrzeuge_node.html.

Bundesministerium des Innern und für Heimat (2025). *Zivil- und Katastrophenschutz*. URL: https://www.bmi.bund.de/DE/themen/bevoelkerungsschutz/zivil-und-katastrophenschutz/zivil-und-katastrophenschutz-artikel.html.

Coppola, D. (2006). *Introduction to International Disaster Management*. Elsevier.

Elbez, R. and Alevantis, T. (2004). "The Role of CECIS – Common Emergency Communication and Information System". In: *Proceedings of the 1st International Workshop on Information Systems for Crisis Response and Management (ISCRAM 2004)*. Ed. by B. Carlé and B. Van de Walle. Brussels, Belgium, pp. 81–85.

European Commission (Jan. 2026a). *Emergency Response Coordination Centre (ERCC)*. European Civil Protection and Humanitarian Aid Operations. URL: https://civil-protection-humanitarian-aid.ec.europa.eu/what/civil-protection/emergency-response-coordination-centre-ercc_en.

European Commission (Jan. 2026b). *European Civil Protection Mechanism*. European Civil Protection and Humanitarian Aid Operations. URL: https://civil-protection-humanitarian-aid.ec.europa.eu/what/civil-protection/eu-civil-protection-mechanism_en.

European Commission (Jan. 2026c). *European Civil Protection Pool*. European Civil Protection and Humanitarian Aid Operations. URL: https://civil-protection-humanitarian-aid.ec.europa.eu/what/civil-protection/european-civil-protection-pool_en.

Federal Emergency Management Agency (2018). *ICS Review Document: Extracted from E/L/G 0300 Intermediate Incident Command System for Expanding Incidents (ICS 300)*. Federal Emergency Management Agency.

Federal Emergency Management Agency (2024). *20 Years of the National Incident Management System*. U.S. Department of Homeland Security.

Federal Emergency Management Agency (2025a). *National Incident Management System (NIMS)*. U.S. Department of Homeland Security. URL: https://www.fema.gov/emergency-managers/nims.

Federal Emergency Management Agency (2025b). *Resource Inventorying (RIS)*. Preparedness Toolkit – National Resource Hub. URL: https://preptoolkit.fema.gov/web/national-resource-hub/resourceinventorying.

Federal Emergency Management Agency (2025c). *Resource Typing Library Toolkit (RTLT)*. Preparedness Toolkit – National Resource Hub. URL: https://rtlt.preptoolkit.fema.gov/Public/Home/About.

Hellmund, T., Moßgraber, J., Schenk, M., Hertweck, P., Schaaf, H. van der, and Springer, H. (2021). "The design and implementation of ZEUS: Novel support in managing large-scale evacuations". In: *Proceedings of the 18th ISCRAM Conference*. Ed. by A. Adrot, R. Grace, K. Moore, and C. Zobel. Blacksburg, VA, USA.

Hellmund, T., Schenk, M., Moßgraber, J., Springer, H., Reuter, J., and Hertweck, P. (2022). "ELD-BS: The digital situation dashboard for Baden-Württemberg". In: *Proceedings of the 19th ISCRAM Conference*. Tarbes, France, pp. 233–240.

Hellmund, T., Schenk, M., and Schaaf, H. van der (2025). "OData – The best way to develop crisis management tools? A qualitative and quantitative assessment". In: *Proceedings of the International ISCRAM Conference*.

ISO/IEC (1998). *Information technology – Open Distributed Processing – Reference Model: Overview*.

Karutz, H., Geier, W., and Mitschke, T., eds. (2021). *Bevölkerungsschutz: Notfallvorsorge und Krisenmanagement in Theorie und Praxis*. Springer VS.

Kilov, H., Linington, P. F., Romero, J. R., Tanaka, A., and Vallecillo, A. (2013). "The Reference Model of Open Distributed Processing: Foundations, experience and applications". In: *Computer Standards & Interfaces* 35.3, pp. 247–256.

Land Baden-Württemberg (2025). *Gesetz über den Katastrophenschutz (Landeskatastrophenschutzgesetz – LKatSG) vom 9. Dezember 2025*.

Ministerium für Inneres, Digitalisierung und Migration Baden-Württemberg (2019). *Verwaltungsvorschrift des Innenministeriums über die Stärke und Gliederung des Katastrophenschutzdienstes (VwV KatSD)*.

Niedersächsisches Landesamt für Brand- und Katastrophenschutz (2023). *Gliederung und Sollstärke der Einheiten im Katastrophenschutz (Gliederungserlass)*. URL: https://www.nlbk.niedersachsen.de/startseite/katastrophenschutz/rechtsgrundlagen_katastrophenschutz/gliederung_und_sollstarke_der_einheiten_im_katastrophenschutz_gliederungserlass/.

Niedersächsisches Landesamt für Brand- und Katastrophenschutz (2025). *KatS-StAN NDS: Stärke- und Ausstattungsnachweisungen für den Katastrophenschutz Niedersachsen*. URL: https://www.nlbk.niedersachsen.de/startseite/katastrophenschutz/rechtsgrundlagen_katastrophenschutz/kats_stan_nds/kats-stan-nds-222618.html.

Spinuzzi, C. (2005). "The Methodology of Participatory Design". In: *Technical Communication* 52.2, pp. 163–174.

T-Systems International GmbH (Nov. 2023). *Digitalisierung beim Katastrophenschutz in Nordrhein-Westfalen*. URL: https://www.t-systems.com/de/de/insights/newsroom/news/digitalisierung-bei-katastrophenschutz-in-nrw-632282.