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Designing Resilient EMS Operations: A Business Continuity Perspective on Impactful Emergency Medical Response

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When people are injured or ill, they rely on Emergency Medical Services (EMS) for immediate assistance. EMS provide urgent medical care and transports patients to hospitals, making them a vital component of the public health system. The availability and effectiveness of these services determine whether individuals receive timely and adequate medical attention. As such, EMS are an integral part of a nation's critical infrastructure and are therefore held to high standards of resilience. Although emergency response organizations and their processes can, at an abstract level, resemble many other organizations, they differ considerably in operational detail. As a significant characteristic, EMS must respond effectively to crises while ensuring their own operational continuity during such events. This duality demands specialized processes and resources. This paper explores how EMS can maintain functionality while delivering impactful medical response. It examines business processes of EMS and their related dependencies and supply chains. By contrasting relevant factors for effective operations with associated hazards, potential weaknesses are identified and described. Eventually, general key design characteristics for suitable Business Continuity Management (BCM) in EMS are suggested.

Keywords: Critical Infrastructure, Business Continuity Management, Emergency Medical Services, Ambulance.

1. Introduction

Emergency services are often regarded as the last line of defence against hazards. Whenever individuals require urgent medical assistance due to illness, injury, or accidents, Emergency Medical Services (EMS) are expected to respond without delay. As a result, EMS form a critical component of a nation's public health infrastructure and its broader crisis management system. Their unique role places exceptionally high demands on reliability and availability, as any disruption to EMS operations can have serious consequences for patients and society at large.

Business Continuity Management (BCM) aims to strengthen operational resilience by providing a "management system that seeks to protect against, reduce the likelihood of the occurrence of, prepare for, respond to, and recover from disruptions when they arise." (Galaitsi et al., 2023) Given the mission-critical nature of EMS (Van Stralen and Mercer, 2013), their ability to remain functional under any circumstances seem particularly relevant. However, despite its widespread use in other sectors, the application of BCM to emergency services has received limited attention in academic research so far.

Against this background, this article examines EMS operations and their vulnerabilities in order to identify key considerations for Business Continuity measures. Therefore, the current landscape of critical infrastructure protection and resilience is explored, while elaborating the relevance for EMS. Further, EMS operations are outlined from a system perspective and relevant quality criteria are examined, before distilling potential vulnerable operational aspects. Eventually, considerations for the design of BCM systems for EMS are suggested.

2. Recent Developments in EU Critical Infrastructure Resilience

Critical infrastructures and their protection have been at the heart of EU policy over the last decade with a strong focus on the digital and the physical domain.

With the development and publication of the first version of the Directive on Security of Network and Information Systems (NIS Directive) in 2016 (European Comission, 2016), the European Commission fostered the (re)harmonization of the concept of "critical infrastructures". Therein, specific sectors were defined that were considered as "critical" all over the European Union; however, EMS was not among them.

In 2022, the NIS directive was extended to a second version, i.e., the NIS2 Directive (European Comission, 2022b), which defines a larger number of critical sectors and integrates a stronger focus on the supply chain of these sectors. The NIS2 Directive keeps the concept of "operators of essential services" from NIS1 but defines "essential entities" and "important entities" instead of "operators". The focus of the extension was a broader scope on the economy and thus includes more sectors which are important for the European society, with public healthcare providers being included and therefore relevant for EMS. The main goal was to strengthen the cooperation and information exchange between the Member States, their authorities and organizations in case of cybersecurity incidents and to enforce a more stringent cybersecurity culture on management level and in supply chains.

At the same time, the Critical Entities Resilience Directive (CER Directive) was established (European Comission, 2022a), which extended the NIS2 Directive from a content perspective by focusing on physical protection and resilience instead of communication and information systems. NIS2 and CER mostly share the same set of critical sectors and therefore both regulations are relevant for EMS. Hence, it became a necessity for such services to secure their digital and physical processes. Therefore, implementing BCM now became a vital and ultimately legal requirement, which poses a challenge to EMS organizations.

3. EMS as a process

EMS vary considerably in organizational structures and legal frameworks across countries (Organization, 2008), yet share a common functional core: the provision of time-critical pre-hospital medical care and patient transport following an emergency call. In this paper, EMS are understood as ground-based emergency response organizations. Airborne Helicopter Emergency Medical Services (HEMS) are excluded due to their distinct operational and continuity characteristics. The operational scope extends from emergency call reception to hospital handover and subsequent re-establishment of operational readiness. EMS occupy a consistent function within the chain of rescue, which describes the sequence of actions and actors involved in providing assistance from the occurrence of an emergency to definitive clinical care. This chain typically comprises first aid by bystanders, emergency call handling, emergency medical response, and hospital-based treatment (Schmiedel and Betzler, 1999b). Within this sequence, EMS form the link between emergency communication systems and hospital care. Being embedded in this wider system of aid, EMS operate as a socio-technical system in which human actors, technical infrastructure, organizational procedures, and external interfaces interact under conditions of high time pressure and uncertainty. Emergency situations in this paper are characterized by incomplete, ambiguous, or rapidly changing information, requiring time-critical decisions regarding resource allocation, medical treatment, and patient transport.

From an operational perspective, EMS can be structured into a sequence of primary process steps spanning a single emergency response cycle between emergency call reception and hospital handover. While presented sequentially, these steps are interdependent and linked through shared resources, time constraints, and external dependencies.

Emergency call-handling marks the entry point of the process. Incoming emergency calls are received, assessed, and prioritized based on limited and often uncertain information. Decisions made at this stage shape the entire response by influencing urgency classification and resource selection. **Alerting** translates the assessment of the emergency call into the mobilization of appropriate resources. Dispatch decisions determine which units are alerted, directly affecting response times, coverage of the service area, and the availability of resources for concurrent or subsequent emergencies. During **approach to the emergency scene**, EMS units are exposed to external conditions such as traffic, weather, and infrastructure availability. Delays at this stage can significantly affect patient outcomes and reduce overall system capacity. **Arrival on scene** initiates direct interaction with the patient and the operational environment. EMS personnel must rapidly assess the situation, ensure scene safety, and adapt to dynamic conditions that may differ substantially from the information provided during the emergency call. **Patient assessment and care** constitute the core medical activity. Clinical decisions are made under time pressure and resource constraints, often requiring prioritization between stabilization, on-scene treatment, and rapid transport. If indicated, **transportation of the patient** involves maintaining medical care while coordinating with receiving hospitals. This step introduces a strong dependency on hospital admission capacity, as delays in patient handover can immobilize EMS units and reduce the system-wide ability to respond. **Hospital handover** marks the transition of responsibility to clinical care facilities. Efficient handover processes are essential, as prolonged handover times directly delay the re-availability of EMS resources. Finally, **re-establishment of operational readiness** ensures that vehicles, equipment, and personnel are restored to a deployable state. This step is critical for sustaining service capacity, particularly during periods of high demand, as delays accumulate across deployments and reduce the ability to respond to new emergencies.

4. Building resilient EMS

Crises such as the COVID-19 pandemic have shown that EMS operations are vulnerable to prolonged system-wide stress. (Alruwaili, 2024) At the same time, more localized disruptions, such as the sudden unavailability of facilities or infrastructure(ANSSI, 2021; Koks et al., 2021), can equally impair service effectiveness. Similar to most emergency response organizations, EMS can be considered as services provider (Kern and Hartung, 2013), and their service is performed through a single, clearly defined process: critical, pre-hospital treatment and patient transport to clinical care. However, sustaining this service requires the coordinated functioning of numerous resources, support processes, and dependencies on external entities under conditions of urgency and volatility.

Since EMS are encompassed by the recent legislation mentioned in Section 2, there is the need to establish BCM systems to maintain their service under difficult conditions. Widely recognized Frameworks, such as the BCI Good Practice Guidelines (BCI, 2023) or ISO standard 22301 (ISO, 2019) provide guidance. As a baseline for the development of resilience measures, they suggest to conduct a Business Impact Analysis (BIA) to identify vulnerabilities in the established business processes and to understand how a disruption of the organization's functions and processes affects its ability to operate. (Krahulec and Jurenka, 2015; Hassel and Cedergren, 2021) Together with an understanding of an organization's goals (Kern and Hartung, 2013) the BIA-output can then be used to analyze risks posed to the organization's mission and service-portfolio as well as to design suitable resilience measures. (Torabi et al., 2016) However, other than in regular BCM systems, risk assessments for emergency responders need to be understood two-fold, i.e., they have to assess risks to their own operations and, at the same time, consider the risks they respond to as emergencies (as this is the primary reason for their operations). (Kern and Hartung, 2013; Hassel and Cedergren, 2021)

Without focusing on a specific organization, this article adopts a generalized, process-oriented perspective to identify aspects of EMS operations that are essential for effective emergency care and thus should be considered when implementing a BCM system and conducting a BIA.

4.1. *Quality of service*

The performance of EMS operations is defined by the quality of their service and can be described in the following eight dimensions (Redelsteiner et al., 2007): To start with, **ensured availability** simply states that EMS must be available and functional and **accessibility** means that people in need must be able to reach EMS via state-of-the-art means of communication. From a more personal perspective, **humane, compassionate care** indicates that interactions with EMS must be empathetic with people in need of assistance; similarly, **appropriateness** states that EMS resources must be suitable, in quality and quantity, to conduct their service. **Timely action** is a core aspect, as the arrival of emergency services at the scene of an emergency must be commensurate with the urgency of the emergency. Scientific findings on the maximum time frame must be taken into account. Further, **Evenness** clarifies that EMS must be available to everyone to the same extent; there must be no differences in provision between urban and rural areas. From an outcome perspective, **cost-effectiveness** indicates that the best possible care must be ensured with the funds available and, finally, **better patient outcome** states that the presence of EMS must result in a measurable improvement in patient well-being (e.g. lower mortality rates, shorter hospital stays, etc.).

These dimensions, although generic, provide a good orientation when preparing a BIA for EMS. Degradation in any of these dimensions may compromise patient outcomes, system availability, or the ability to respond to subsequent emergencies (as we will discuss in the following subsection). Due to EMS' central position within the chain of rescue, these effects do not remain isolated but may interrupt the continuity of the rescue chain and propagate to downstream actors, most notably receiving hospitals.

4.2. *Primary operational process*

Besides quality of service, the operational performance of EMS is equally important and one can impair the other. Operational performance depends on the coordinated availability of trained personnel, response vehicles, medical equipment, communication and dispatch systems, and supporting facilities. These elements are tightly coupled among each other and describe the primary operational process. Disruptions affecting individual components in this process can rapidly impair overall service provision and quality; in more detail, by contrasting the quality dimensions with each step in the primary process (see Fig. 1), it is possible to examine which aspects of EMS operations are affecting the quality dimensions and therefore cause service vulnerabilities. This mapping approach highlights where specific quality requirements are particularly relevant and supports the identification of e.g., critical secondary processes, resources, and stakeholders dependencies. It was conducted in two workshops with subject matter experts, and further explored by additional desk research.

	Emergency call-handling	**Alerting**	**Approaching scene**	**Arrival on scene**	**Patient assessment & care**	**Transportation of patient**	**Hospital handover**	**Re-establishing readiness**
Ensured availability		x						x
Accessibility	x							
Humane, compassionate care	x			x	x	x		
Appropriateness		x			x			x
Timely action	x	x	x	x	x	x	x	x
Evenness								x
Cost effectiveness		x						x
Better patient outcome	x	x	x	x	x	x	x	x

Fig. 1. Mapping of quality dimensions (Redelsteiner et al., 2007) to process phases in emergency medical services

4.2.1. *Ensured availability*

The provision of EMS can generally be described as relevant to the entire process. Essentially, an ensured EMS means that teams are available and can be addressed to respond to emergencies. Eventually, these resources must be ready for service, equipped and staffed with assigned, serviceable and qualified personnel.

4.2.2. *Accessibility*

EMS providers must be able to receive and process emergency calls. In addition to the necessary technical equipment, premises and staff are required, organized in a control room with a dedicated team.

4.2.3. *Humane, compassionate care*

For this quality dimension, process steps are relevant where interaction between patients and EMS personnel occurs, i.e., during the response to the emergency call and for the period in which patients are directly cared for by the emergency services team. Staff must receive appropriate training and possess the necessary interpersonal skills.

4.2.4. *Appropriateness*

The decision which emergency unit is considered appropriate is primarily made during the alerting process. Uhl et al. (2025) However, in order to make a choice, suitable resources must also be ready for use and available in sufficient numbers. Additionally, the team dispatched must take appropriate measures to treat emergency patients according to their medical condition. Therefore, the assessment and organization of resources must be tailored to the geographic service area, its hazards, population, etc. If necessary, it must be possible to contact and call in more medically or tactically suitable resources (e.g. helicopters or specialized medical teams).

4.2.5. *Timely action*

Emergency assistance must arrive quickly at the scene of an emergency. The time between an emergency call and the arrival of the emergency services at the scene is crucial for patients. However, situations also may occur, where a rapid transport to the hospital is necessary, due to a patient's health status. Furthermore, restoring operational readiness after a hand-over at the hospital is time-sensitive as well, especially in times of high demand with few available ambulances in the area of operation. Therefore, timely action plays an essential role throughout all steps of the process. This feeds into the spatial positioning of resources at suitable locations. Ambulance stations and emergency resources must be located in such a way that assistance can be provided as quick as possible. (Behrendt and Schmiedel, 2004)

4.2.6. *Evenness*

The provision of services to the population must be ensured evenly. Parts of the population in the area of operation must not expect a significantly better or worse quality of service than others. This can manifest itself in differences in staff qualifications or quality of resources. The aspect of uniform coverage must also be taken into account here (see 4.2.5 ”timely action”).

4.2.7. *Cost effectiveness*

Financing of the whole EMS operations must be ensured. This must be taken into account in all rescue service activities but is particularly emphasized in two process steps (see Fig. 1). Due to their logistical role, dispatch centers have a significant influence on the economics of rescue services. (Kumpch and Luiz, 2011) Cost-effectiveness must be taken into account when alerting, for example, in order to prevent avoidable wear and tear on the vehicle fleet or overtime for staff. Furthermore, the readiness of EMS resources is dependent on sufficient financing. (Schmiedel and Betzler, 1999a)

4.2.8. *Better patient outcome*

Given its high importance, this quality dimension is relevant for all process steps. To consciously ensure a better patient outcome, the implementation of a comprehensive quality management system is necessary. (Piedmont et al., 2018; Hellmich, 2010) This allows the quality of the service provided to be monitored, controlled and improved. It also serves as a basis for establishing a BCM system.

5. Vulnerabilities in EMS Operations

When analyzing the relations between the process of emergency operations and the quality dimensions, we can identify the following list of vulnerable elements in EMS operations:

- Personnel capability and capacity
- Vehicle fleet
- Equipment, medical consumables and medicinal products
- Communication and dispatching capabilities
- Suitable and well-located facilities
- Funding

The vulnerability is based on the assumption that an operation cannot provide sufficient quality with one of those elements compromised or disrupted. Therefore, measures must be taken to ensure the availability and functionality of those elements, as we will explain in the following subsections.

5.1. *Personnel*

The availability of trained and fit for service personnel is a necessity for operating EMS in any process. This includes emergency medical staff, e.g., paramedics, and administrative staff, e.g., management or dispatch. As an example, disruptions due to staff shortages were noticed during the German Ahr Valley floods in 2021, when the infrastructure in the affected area was severely damaged and workers could not reach their stations. The problem continued until the re-establishment of streets, bridges and rails. (Kowalzik and Hähn, 2021)

Additionally, when it comes to initializing BCM procedures, it must be ensured that staff is trained sufficiently; only in this case BCM measures can be expected to work.

5.2. *Vehicle Fleet*

A functional fleet is required to reach emergency scenes, transport teams, equipment and patients. Similar to staff, vehicles are required in a sufficient number and need to be fit for service. However, a particular challenge is the high dependence on external service providers and suppliers for fleet management. Due to technical advancements in vehicles, maintenance is becoming increasingly complex. Accordingly, the ability for independent maintenance or simple repairs is becoming increasingly limited. However, to maintain a functional fleet, EMS must be able to guarantee required maintenance and repair measures and to have necessary operating resources, i.e., fuel, spare parts, cleaning and disinfecting agents, etc.

5.3. *Equipment, medical consumables and medicinal products*

Emergency services use a wide range of different equipment to respond injuries and illnesses. Therefore, equipment must be ready to use, held in sufficient quantities and represent the state-of-the-art. Like vehicles, devices and materials require ongoing care, maintenance and replacement. Particular attention must be paid to medical devices, which often must comply with country-specific legal requirements and undergo regular inspections. These inspections are often carried out by the manufacturing companies or other external partners and cannot be performed independently by many emergency services. E.g., if manufacturers would recall products, this would leave EMS without important equipment, if no redundancies were created. A prominent case is the mass recall of defibrillators in 2005, which are required to treat patients with cardiac illnesses. (USFDA, 2026)

5.4. *Communication and dispatch systems*

To be capable to communicate and to control resources is a major functional requirement. This includes communication between EMS entities, as much as communication with emergency callers, via telephone, internet, radio, etc. In this context, control rooms can be identified as vital information hubs, which need to be included in vulnerability assessments. Especially the topic of communication makes it necessary to extend the scope of any BIA from physical risks to the cyber domain. This was tragically shown during the emergency number outage in June 2021 in France, which has been analyzed to have caused 11.800 emergency calls to be left unanswered. (ANSSI, 2021) Although caused by the failed systems of a telecommunication provider, critical functions of EMS were affected and need to be addressed by internal resilience measures and redundancies.

5.5. *Facilities*

EMS rely on a range of facilities to ensure the continuous provision of their services. These properties serve different purposes, e.g., ambulance stations, offices or control centers, each of which must meet specific functional requirements. If ambulance stations become unavailable, response times increase as vehicles must be dispatched from more distant locations, potentially endangering regional coverage. Emergency personnel depend on these facilities over the long term to meet basic needs, maintain equipment, and ensure operational readiness. Consequently, the availability, structural integrity, and technical functionality of buildings are critical. Key building functions include, e.g., electricity, HVAC, sanitation, resting opportunities, physical security, parking, offices, storage, or hygiene. Events such as the 2021 floods in Germany demonstrated the vulnerability of emergency service infrastructure (Koks et al., 2021), requiring damaged ambulance stations to be replaced by temporary set-ups, such as office containers.

5.6. *Funding*

Secure economic capacity is essential for maintaining EMS operations. In particular, this includes the ability to pay salaries and settle invoices, which requires stable and cost-covering financing. Financial instruments and payment systems must be secured in such a way that disruptions at financial institutions do not lead to operational failures. Internal systems for documenting operations and billing services must also be secured. In the case of full or partial financing through donations or sponsorship, it is important to ensure transparency regarding sources of funding, their significance and existing dependencies, as these act as critical suppliers for the continued operation of the service.

5.7. *Dependencies related to clinical infrastructure*

One essential aspect of successful EMS operations is that patients can be handed over to other institutions, e.g., hospitals. Only if a patient is handed over, the EMS team can continue to reestablish their readiness and respond to the next emergency. This reveals a critical dependency on hospital capacities since overwhelmed hospitals lead to blocked ambulances without the means to continue their business. This is a dependency that can rarely be controlled by EMS and needs to be solved on a meta-organizational level, especially if EMS providers and hospital providers are not under a common management.

6. Outlook

The operational elements described in this article provide an overview of possible vulnerabilities which have the potential to compromise EMS operations. While EMS providers are constituted in varying organizational structures and legal frameworks, the aspects described above are limited to common attributes and challenges, which unite them. Since BCM systems for emergency response organizations, especially EMS, have not been discussed extensively in research yet, this article highlights an entry point for further academic discourse. The recent legislative changes related to resilient critical infrastructure are a step towards more strengthened emergency services and require many of them to implement designated BCM systems, risk management approaches and cybersecurity measures for the first time. From a research perspective, this opens opportunities for case studies and empirical practice, which then may benefit more emergency response agencies in not just protecting others, but to essentially in being able to protect themselves.

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