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3.4.1 Emergency infrastructure and facilities

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1 Introduction

Emergency facilities and infrastructure are essential assets for society, but they need to maintain their resilience and operational continuity.

Emergency facilities and infrastructure (EMFIs) are essential components of society's mechanism, as they can make the difference in addressing crises. For example, fire engines, police cars or ambulances deploy from a backbone of stations and coordination centres that have the duty to respond to adverse conditions that could disrupt the functions of a community. EMFIs are part of the vital networks and assets that allow the delivery of emergency services, which are defined by the United Nations Office for Disaster Risk Reduction as 'a critical set of specialised agencies with specific responsibilities and objectives in serving and protecting people and property in emergency situations' (UNISDR, 2017). They include first responders, such as fire service personnel, police, primary healthcare operatives, civil protection responders and local authority workers.

Their structures, jurisdictions and organisation depend on national legislations and regional contexts. EMFIs are intended to be highly resilient, and they can often be seen as strongholds designed to withstand all levels of external (operational) and internal (organisational) pressure. They should have reliable emergency and operational continuity plans to help them avoid failures that could potentially compromise the delivery of relief (Lindell et al., 2007; Alexander, 2016). However, this is far from being the whole truth. If there are gaps in their preparation strategy and if some threat has been underestimated, they can be disrupted and the whole emergency sector may be affected, leading to hiccups in emergency support.

At the international level, emergency facilities have been mentioned in some major global agreements that provide guidance for policies and practices, such as the Sendai framework for disaster risk reduction (SFDRR). This has been adopted by UN Member States as a follow-up to the Hyogo framework for action, and it includes seven targets and four priorities areas intended to 'prevent new and reduce existing disaster risk' (UNISDR, 2015). The SFDRR identifies key actions on emergency facilities to be taken within multiple priority areas.

The reality in which EMFIs operate has evolved as technology has developed, and this chapter provides a basic understanding of the new challenges to their operational continuity and organisational resilience. The next subsections will identify possible guidelines for management designed to ensure that lifelines can respond to complex events. First, they introduce the operational role of lifelines in the disaster cycle. Secondly, they explain some key challenges to organisational resilience. These are clarified using case studies and examples. In conclusion, the chapter defines how to adopt practical steps to increase operational continuity and organisational resilience. For feasibility, the focus is on those facilities and infrastructure involved directly in the management of events and does not include those that can be used for emergency evacuation or shelter, such as education facilities (Lindell et al., 2007; Alexander, 2016).

2 Role in the disaster cycle

Emergency facilities and infrastructure are essential in all phases of the disaster cycle, but their operational context changes and needs to be understood.

According to both scholars and practitioners, there are phases in the process of dealing with disasters (Coetzee and Van Niekerk, 2012). These are usually considered to be mitigation, preparedness, emergency response, recovery and, in some approaches, reconstruction. The cycle has considerable utility in both planning and teaching or training. However, not all scholars and practitioners accept it.

For example, Neal (1997) observed that the phases might not be fully consecutive. Kates and Pijawka (1977) also noted the overlap between parts of the cycle. Historically, there has been an emphasis on the emergency response phase, but it is not the only element to consider in crisis management.

EMFIs are not only the hub of response activities, but they are also the natural home of various forms of planning, including those that pertain to hazard and risk mitigation, and to recovery of basic assets and infrastructures. The natural hub of operations varies from one country to another, depending on which is the lead agency and how interagency relations are organised in the national system (Alexander, 2007).

For example, in the United Kingdom the lead agency is often the police force, as emergencies have traditionally been considered to be a matter of public order. In Germany and Italy, it is the fire service, as technical rescue and scene management dominate the early stages of emergency intervention. Dynamic forces such as globalisation, urbanisation and just-in-time economics have helped change the landscape in which EMFIs operate and are maintained (Helbing, 2013; Linkov et al., 2014; Alexander, 2016).

For example, tools such as the Global Positioning System (GPS) and other global navigation satellite systems have been used intensively to improve the coordination and deployment of resources, but they have also created a network of hidden interdependencies that could compromise operation capacities if they are not mitigated (Pescaroli et al., 2018). Similarly, budget cuts have created the conditions for the development of more effective procedures but have also compromised the redundancies and buffering options that are essential safeguards in this sector.

Wherever a nation's emergency response system is placed on the continuum from command and control to cooperation and collaboration, the functionality and sustainability of the system depend on how it performs under pressure. Planning and redundancy are two of the possible solutions, but both are expensive, and EMFIs easily become a target for cuts in times of austerity.

3 Challenges for operational continuity and organisational resilience

Cascading effects and compounding dynamics can challenge the organisational resilience and operational continuity of emergency facilities.

The capacity of EMFIs to maintain the continuity of operations presents multidimensional challenges in contemporary disaster management, which is distinguished by the presence of complex scenarios (UNISDR, 2017). Indeed, organisational resilience goes beyond the functionality of buildings hosting vital assets or services, including also the interrelation between technological and societal drivers (Hellstrom, 2007; Sommer and Brown, 2011). Three main dynamics have to be considered as key emerging challenges to be integrated into policies and planning strategies in the future.

(a) Direct involvement of EMFIs at the 'epicentre' of a crisis. Increased urbanisation, diffusion of vulnerability in the urban environment and climate change make it likely that buildings are in areas that are at risk from primary threats such as flooding or heatwaves (Birkmann et al., 2014). The high degree of reliability required of structural mitigation measures and safety practices, and the changing patterns of urban vulnerabilities may lead risk to be underestimated. For example, this may be the case for command centres located in floodplains or near sites that become possible terrorism targets when the security environment changes, as happened in 2017 to the London Fire Brigade, whose headquarters are located near the site of the London Bridge attacks of that year.

(b) Impact on EMFIs of cross-sectoral cascading effects. Instead of being stabilised by the mobilisation of emergency resources, the crisis escalates as time progresses, and spreads because of the innate vulnerability of society and the disruption of interconnected infrastructure nodes (Pescaroli and Alexander, 2018).

(c) Complex scenarios and compound and interacting drivers, such as the concurrence of natural hazards. This refers to the concurrence of two or more events that are extreme either from a statistical perspective or by being associated with a specific threshold (Field et al., 2012). For example, demand on EMFIs may increase because of wildfires during a heatwave or drought. Other elements of complexity can be referred to interactions between hazards, for extreme heat triggering an avalanche, or earthquake triggering a tsunami (Pescaroli and Alexander, 2018).

The next two subsections will develop points (b) and (c) further, as their implications for organisational resilience are more complex to understand.

3.1 Impacts on EMFIs of cascading effects

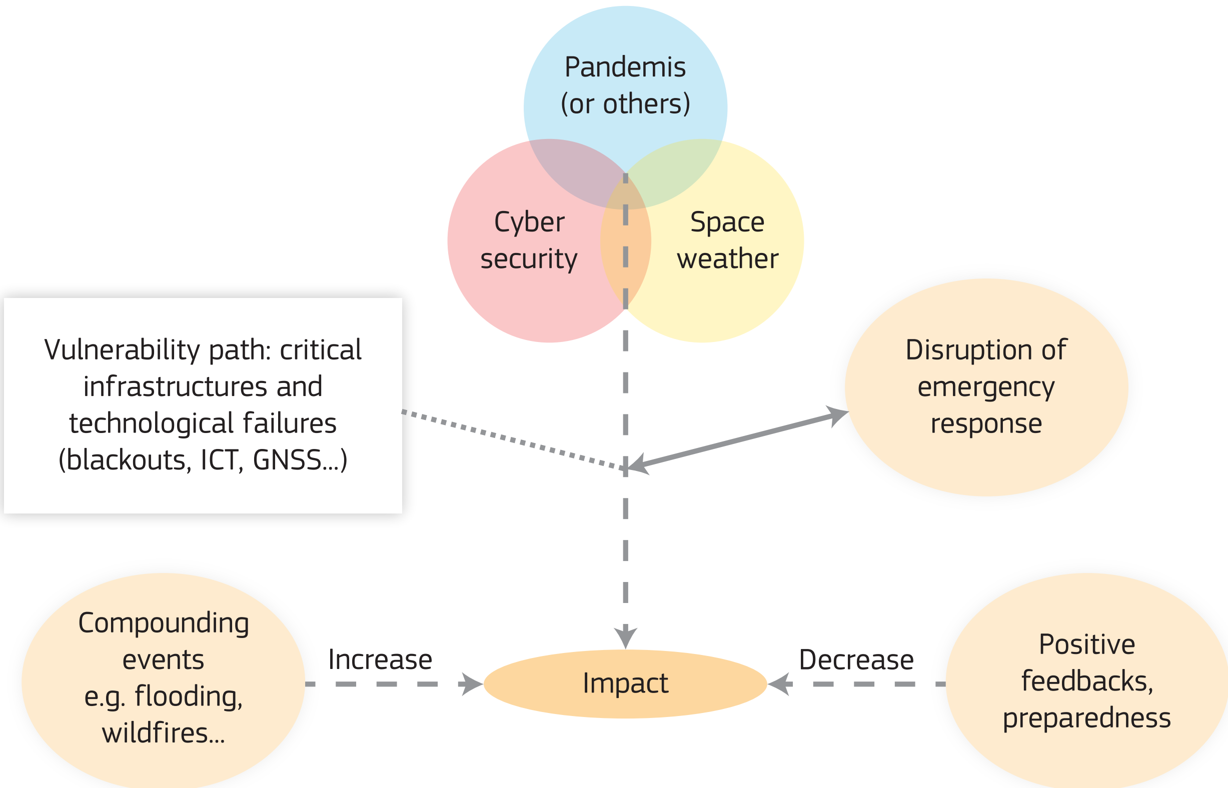
In general, when disasters and crises are triggered, increased pressure on EMFIs can be always be observed. However, their organisational resilience and operational continuity can be challenged by cascading effects that originate in other infrastructure sectors. This can arise as a result of multiple shortfalls of vital supplies, such as electricity, petrol, food, water, hygiene, drugs and personal communication systems. For example, power failures can reduce the energy available for operations, creating both communication disruptions that compromise the internet and transport disruption affecting logistics (Petermann et al., 2011; Van Eeten et al., 2011).

Preparedness for multiple failures can be underestimated or neglected owing to the complexity of the interrelationships that need to be taken into account in planning (Alexander, 2016). For example, changes in the working environment associated with flexible hours, and the evolution of the urban landscape due to inequality or gentrification, may lead to understaffing of command centres in scenarios of public transport failures. In other words, when there are extended disruptions of public transport and communication, it has to be assumed that some personnel will not be available. Therefore, emergency procedures need to be in place to ensure the presence of essential staff, and lifelines have to be reassessed. Operational continuity needs to be made sustainable and resources need to be maximised. Awareness of possible interdependencies needs to be increased by adopting new scenario-building processes that aim to understand common vulnerabilities to multiple threats (Pescaroli et al., 2018).

3.2 Complex scenarios and compound and interacting drivers

In the future, climate extremes will make it possible for cascading effects to recombine with compound drivers. This could lead to scenarios in which initial events of variable intensity, such as a local or regional flood, may coincide with a technologically driven escalation, as shown in Figure 1 (Pescaroli et al., 2018).

Figure 1. *Disruption of operations scenario associated with technological failures and compounding events.*
Source*: Adapted from Pescaroli et al., 2018.*



Primary triggers could originate in the natural domain, as when storm-force winds cause a blackout during a cold wave, or they could potentially be associated with malicious intents, as when cyberattacks aim to disrupt emergency operations. In other words, emergency management could require action to contain primary threats while at the same time being challenged in scaling up processes that are highly reliant on technological resources. Knock-out scenarios are far from implausible. In September 2017 the strongest solar flare in 12 years caused radio and GPS communications to deteriorate while, in the wake of Hurricane Harvey, Hurricane Irma was challenging emergency services on Atlantic coastlines (Crane, 2017).

While there is no evidence that the solar flare complicated the provision of relief, it affected the same hemisphere. Moreover, it has been suggested that shocks to the cyberdomain could be triggered by attacks on critical infrastructures during some other type of crisis, which could limit the capacity of technicians to activate protection measures (Sommer and Brown, 2011). An additional example can be considered by analysing the 2020 coronavirus (COVID-19) global pandemic. Just in the first half year since the emergency declarations in Europe, it become evident that the cascading effects of the primary trigger (COVID 19) could re-combine and compound with events such as heatwaves, wildfires, flooding, earthquakes, hurricanes, chemical accidents and targeted cyber-attacks (York 2020, Clark-Ginsberg et al. 2020).

4 Examples and case studies

There are different examples of how cascading effects and compounding dynamics can directly and indirectly disrupt emergency facilities, and provide complementary lessons learned.

The following subsections propose three case studies that have been chosen for their capacity to support the understanding of the points explained above. The triggering events included two cases of flooding in small to medium-sized urban areas, representing high-frequency hazards of the most common kind. Each of the case studies refers to an area of well-known risk, in which other events followed the main impact, and also involves a recent event with few precursors and active lessons to be learned. One case involves extended technological failure during hot weather. This has been chosen because of growing concerns about ageing infrastructure in Europe, and the possible concurrence with climate extremes such as the heatwaves of 2017–2019. The cases are reported in chronological order, first describing the background and then identifying the lessons learned. The principles that have been discussed apply to most of the other human-made or natural threats, such as earthquakes, forest fires, volcanic eruptions or cyberattacks. In other words, the section uses an all-hazards approach by proposing an analysis of the effects that could be common to different triggers. Practical suggestions about organisational resilience for decision-makers are given subsequently.

4.1 Power outage in Auckland, February–March 1998

With a 2018 population of approximately of 1.6 million inhabitants, Auckland is the largest city in New Zealand. It is the major economic and financial centre of the nation. It is located on North Island on a volcanic field that is potentially disruptive. During the southern hemisphere summer of 1998, the city experienced an extended power outage of 10 consecutive weeks. This directly affected the central business district, where the economic activities were concentrated. An analysis of the event and its implications for emergency management was conducted by Stern et al. (2003). The crisis was triggered by the failure of four major cables that delivered energy to the city, but it was rooted in unaddressed vulnerabilities, such as lack of adequate maintenance of the grid. In the first instance, emergency services had to deal with demands that are common to wide-area power failures (Petermann et al., 2011; Royal Academy of Engineering, 2016) such as people trapped in elevators, activation of automatic alarms, and pressure on healthcare associated with carbon monoxide poisoning, rotten food and contaminated water. Afterwards, issues of the continuity management of EMFIs came into play. Owing to the failure of telephones and computers, communication between the organisations became harder. The concurrence of the event with summer reduced the working capacity of personnel (Stern et al., 2003). Indeed, many of the buildings suffered public heath issues and failure of ventilation systems. The temperature in offices exceeded 30 °C, which required personnel to be relocated precisely when there was the maximum strain upon their operational capacity. This was particularly true of the facilities located in high-rise buildings, such as the City Council itself.

Lessons learned

Although this case study is now quite dated, it offers various kinds of lesson to learn. First, it shows that, despite high reliability, worst-case scenarios have to be taken seriously. Second, it required workers to balance short- and long-term decision-making as the crisis dragged on and resources and international logistics had to be used sparingly. Finally, it showed that crisis managers themselves can be victims of disruption. Although the event is quite long ago and society has changed since 1998, technological failures concurrent with climate extremes have to be taken seriously and integrated in actual continuity management. For example, the 2018 power network overload in Cascais, outside Lisbon, happened during one of the most severe heatwaves of the decade. In the United Kingdom, summer 2019 was marked by rail transport disruptions in July due to extreme heat, and then a month later a blackout in southern England, where Ipswich Hospital was disrupted during an extended period of severe heat. Moreover, this case study illustrates that multiple levels of cascading effects originating in the energy sector can create cross-sectoral challenges to operational capacity and organisational resilience (Petermann et al., 2011;

Royal Academy of Engineering, 2016). Emergency tools such as generators or stored fuel may be inadequate, while high reliance on contractors could imply loss of lifelines where the crisis implies competition for the same resources, for example when demand for the services of the same contractor is higher than its capacity. The loss of pressure in water mains or heating could compromise the safety of buildings, while reduced telephone capacity during periods of increased demand may overload landlines. Finally, the disruption of technological assets such as servers and data centres could imply shifting to paper-based procedures, as well as requiring tools for individual resilience such as hand-cranked battery chargers. In both cases, underestimation of risks or cuts in budgets may limit the redundancy of resources. In areas where cashless transactions are common, scenario building should consider the impacts of cross-sectoral failures on emergency personnel independently from the triggering events. Electricity failures may make simple activities, such as grocery shopping, impossibly difficult (Royal Academy of Engineering, 2016). EMFIs are operated by personnel that rely daily on the effective functioning of the same systems as everyone else.

4.2 Flooding in Carlisle, January 2005

Carlisle is an industrial town in Cumbria, northern England. It has a population of approximately 74 000 and it is known to tourists for historic heritage such as the nearby Hadrian's Wall and the Lake District National Park.

The city has several areas at risk of flooding, which happened in 1771, 1822, 1856, 1925 and 1968. In January 2005 approximately 1 600 properties were inundated in the city and three people died. Critical infrastructure disruptions were widespread, which affected emergency relief and rescue. The UK Environment Agency (2006) noted that more than 250 000 homes and business in Cumbria and north Lancashire were affected by power failures, with restoration costs of approximately GBP 4.5 million in Carlisle alone. Moreover, as a consequence of the power outage the mobile phone network was disrupted, as was part of the landline telephone system, further burdening the emergency services. Some of the key personnel were prevented by road closures from reporting for duty. Police stations in Carlisle, Penrith and Appleby were heavily damaged, as were council offices and schools. The official report (Environment Agency, 2006) emphasised that the shutting down of the police station in Carlisle was the first closure of a major station in peacetime.

The closure of the civic centre led to the relocation of the strategic ('gold') command centre, which was directly affected by the flooding. It lost its communication room but managed to remain operational despite heavy challenges. The county Fire and Rescue Service was also disrupted, as a fire station was flooded to a depth of approximately 2.5 metres. The emergency situation required the support of fire and rescue crews from across the United Kingdom.

Lessons learned

According to the UK Environment Agency and Cumbria County Council (2016), the 2005 flooding led to the development of a new flood defence scheme and presented an opportunity to define new flood-warning areas and practices. However, in December 2015, as a consequence of Storm Desmond, the city suffered another major event, with 2 128 proprieties flooded in Carlisle and approximately 60 000 homes subject to power outages across northern England. Although the lessons learned at the emergency coordination centre were implemented, further lessons were derived from critical infrastructure failures in the 2015 flood (Environment Agency and Cumbria County Council, 2016; Royal Academy of Engineering, 2016). First, household preparedness and emergency response were inadequate to face extended blackouts, as noted in the previous example in Auckland. Second, it has been shown that, during the flood, power disruption affected the whole area and a pumping station started to rely on an emergency generator until it ran out of fuel and stopped (Environment Agency and Cumbria County Council, 2016; Royal Academy of Engineering, 2016). The exact time was not recorded, but it had an impact on emergency services, as it led to flood overtopping in some affected areas. In conclusion, it can be noted that the wired telephone system continued to hold up, but mobile phone systems did fail. The need for reliable communications was highlighted as a cross-cutting issue in considering the needs of the public (Royal Academy of Engineering, 2016). To sum up, this case study highlights the need to plan carefully the location of EMFIs, and, if they lie in areas at risk, some alternatives should be identified in the preparedness phase (UNISDR, 2015). Moreover, their resilience to multiple infrastructure failures should be assessed, giving priority to increasing redundancies and buffering (UNISDR, 2015).

The last element to consider in this case study is that complex events may require the development of improved cross-border coordination for fast deployment of emergency teams under mutual aid agreements. Since 2005, the evolution of the EU civil protection machinery has provided a concrete answer to that challenge. However, further work may be needed to prepare for the cascading effects of multiple infrastructure losses, in particular to define the logistics of fast deployment during technological failures and loss of lifelines to emergency facilities.

4.3. Flooding in Parma, October 2014

Parma is a well-known centre of high-quality food production in northern Italy. In 2018 the city had approximately 200 000 inhabitants. Over the period 10–13 October 2014 three of its neighbourhoods were partially flooded, causing EUR 26.5 million of direct economic damage but no loss of life (Protezione Civile Emilia-Romagna, 2015). The majority of the economic damage was associated with the disruption of two pieces of critical infrastructure.

(a) The flooding of the Piccole Figlie hospital (Figure 2), a nearby nursing home and a health care centre for non-self-sufficient elderly people necessitated the emergency evacuation of 96 patients. Although the principal clinic of the hospital was located less than 20 metres from the riverbank, all its functions were still operational until river water entered the building. In a few minutes, flooding reached 1.5 metres and staff had to help the patients, many of whom were elderly, climb onto tables to reach safety. Moreover, the building had an oncology centre, from which 16 patients, some with terminal cancer, had to be evacuated using rudimentary methods (Petri and Ciocci, 2014). The hospital was inoperative for 2 months, which placed a burden on other health services in the city.

(b) Flooding of a telecommunications hub led to the total interruption of both landline and mobile telephone coverage supplied by Telecom Italia in the western portion of Emilia-Romagna for days, and it directly affected the operational capacity of the emergency services (Protezione Civile Emilia-Romagna, 2015). In the affected area, situational awareness was reduced because citizens were unable to communicate with the emergency services. The offices of the city hall had communications disrupted, and the personnel were only able to deliver official communications using the Facebook profile of the mayor. Similarly, general practitioners were unable to communicate with vulnerable patients in the flooded areas. Some calls to the 118 emergency medical number had to be rerouted through the regional emergency network using diverse repeaters.

Figure 2. *Parma during the flooding: the Piccole Figlie hospital*
Source*: Wikicommons, author Comune di Parma (2014), CC BY-SA 2.0*

Lessons learned

The event shows the impact on EMFIs associated with both the direct effects of primary triggers, such as flooding, and the cascading effects of disruption in other critical infrastructure sectors, such as telecommunication. There are different lessons to be learned and gaps to be addressed in the future. First, this case study highlights how hazard and critical infrastructure maps still do not connect with each other. In Parma, the location of the telecommunications hub was known only to the provider. They need to be better integrated with the development of processes, practices and scenarios (Nones and Pescaroli, 2016). As happened in the previous case study, these elements should naturally be considered in continuity management, but this is far from always being the case. The location of emergency facilities may be well known, but their vulnerability may be not be understood because changes in the urban landscape have increased the risk. Moreover, this case study points out the need to assess critical infrastructure interdependencies, and the location of nodes and hubs, but also to integrate cross-sectoral failures and cascading effects with measures to ensure the organisational resilience of the emergency services (Pescaroli and Alexander, 2018).

Coordination issues may become primary challenges to address. At the time of the disruption, the contingency plan needed further work. If information is not shared enough, communication challenges may arise within the emergency services, and between the emergency services and the public. For example, the impacts on the continuity of data of hospitals and healthcare facilities has proven to be particularly critical, affecting both routine operations and emergency management (Klinger et al., 2014). Moreover, a growing tendency for disaster management to be over-reliant on internet services has been noted (Royal Academy of Engineering, 2016; Aldea-Borruel et al., 2019). In Parma, the key factor to contain the crisis was low-tech radio capacity, which was vital to operations when more sophisticated technological solutions failed (Perri, 2014).

Practical solutions to those challenges include the development of alternative procedures and redundancies, such as increasing the sphere of operation of radios in case of extended emergencies, and constructing scenarios of emergency needs with respect to the population of vulnerable people. Finally, warning and preparedness strategies are clearly relevant to emergency facilities, as lack of action can compromise their operational capacity and exacerbate the risks for their beneficiaries. There must be further integration and standardisation across functional sectors (Birkmann et al., 2014).

5 A discussion of guidelines for operational continuity and resilience

The resilience of emergency facilities and infrastructure can be improved by considering both primary threats and cascading effects in checklists and operational standards.

The increased complexity of society requires a shift in emergency planning and management (Helbing, 2013; Linkov et al., 2014; Pescaroli and Alexander, 2018; Pescaroli et al., 2018). Indeed, despite the relatively high reliability of critical infrastructure networks that support lifelines in emergencies, the future is one of complex scenarios of reduced operational capacity. The case studies presented above represent a starting point for further discussion. There are some main elements that can be discussed in considering an all-hazards approach, to support scenario building, exercises, risk assessment and horizon scanning.

- Emergency facilities can be affected by primary threats, and consideration needs to be given to addressing investments in retrofitting and mitigation. The literature shows that emergency facilities such as healthcare facilities are dependent on physical resilience, and non-structural and organisational components such as evacuation planning, staff rotas, time of day at which the event happens and accessibility by road (Birkmann et al., 2014). The online technical guidelines of the World Health Organization (2019) have reported some specific considerations that can be used to understand the impacts of some other recurrent hazards in Europe.

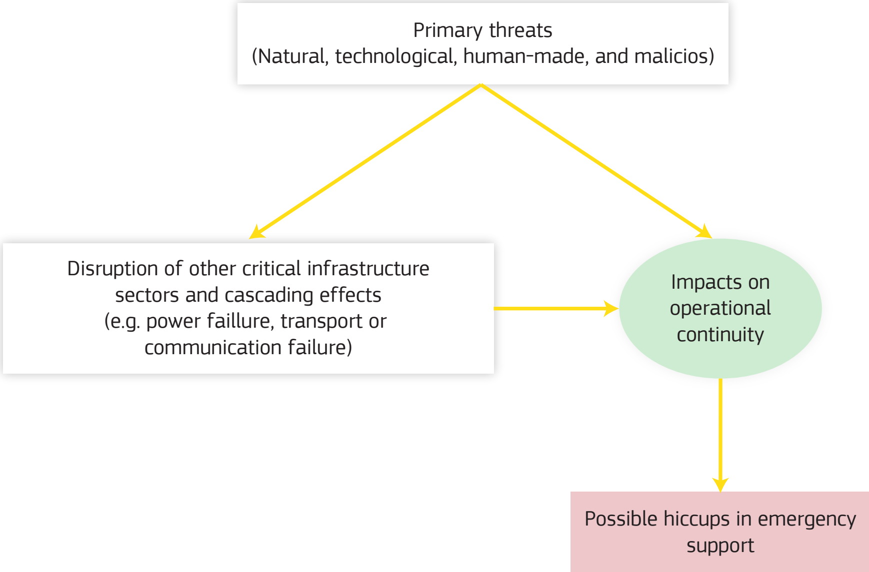
  For example, the effects of earthquakes on hospitals and healthcare facilities can be described in terms of both direct impacts, such as physical damage, and stressors associated with infrastructure failures, such as absence of workforce caused by transport disruption, or the loss of medical supply and procurement. EMFIs can represent a potential target for malicious attacks. The WannaCry ransomware attack in 2017 disrupted one third of hospital trusts, and 603 primary care and other organisations in England (Smart, 2018). The electronic flow of clinical information was compromised, causing the lack of availability of records and test results. Appointments were rescheduled, including visits for cancer patients, while ambulances were diverted and emergency departments became unable to treat patients (Smart, 2018).

- Emergency facilities are vulnerable to cascading effects, technological failures and compound dynamics. Researchers agree that emergency facilities can be widely affected by dependency on infrastructure such as energy supply or telecommunications. However, lessons have not always been adequately incorporated into effective preparedness and training. Helsloot and Beerens (2009) investigated the response to power outages in 2007 in the Netherlands that lasted approximately 3 days and coincided with particularly cold December weather. More than half of the participants in the study highlighted that local governments' response was inadequate. Other exercises highlighted that events such as power failures could hamper backup systems used by EMFIs such as satellite phones, and 'a mechanism to support widely distributed emergency communication is a fundamental need that must be addressed' (Aldea-Borruel et al., 2019, p. 25). Finally, climate extremes and technology could interact in new ways to increase pressure on EMFIs. For example, the heatwave affecting California in 2019 meant that power had to be shut down for safety, to 'prevent equipment from starting wildfires during hot, dry, and windy periods' (Jackson, 2019, p. 1). These shutdowns affected approximately 3 million people.

Figure 3 reports a synthetic overview of possible dynamics that could be exacerbated by lack of preparation. It can be noted that operational continuity can be directly affected by a primary threat, such as floodwaters, earthquakes or malicious attacks. This is the case, in particular, if emergency facilities and infrastructure lie in areas at risk or are exposed to new risks that were not assessed before, such as terrorist attacks, and find themselves at the epicentre of a crisis. However, there could be new stressors and cascading effects associated with critical infrastructure disruptions originating in other sectors during ongoing events, and they could be concurrent with the primary threat.

When the resilience of the EMFIs is not sufficient to stand the impact of a primary threat or the stressors caused by the disruptions, the capacity of emergency support may be reduced or compromised. Unfortunately, with current knowledge it is not easy to produce worst-case scenarios for the escalation of secondary emergencies such as blackouts, telecommunication failures and transport breakdowns. It is often assumed that emergency facilities are safe from primary triggers without committing to regular assessments that evaluate both technological failures and concurrent dynamics. The process could find common escalation paths and thus seek to maximise resource usage and the effectiveness of emergency responses (Pescaroli et al., 2018).

Figure 3. *Factors affecting operational continuity of EMFIs* ***Source***: *Authors*



5.1 Operational standards and checklist

Some frameworks are already available to improve operational continuity and resilience at the strategic and political levels. They will be described in the next subsections. The first element to consider is the development of international standards that can be used as reference for operational continuity and organisational resilience.

The International Organization for Standardization (ISO) and British Standards Institutions (BSI) standards on continuity management (ISO 22301:2019) and organisational resilience (BSI 65000:2014, ISO 22316:2017) provide the framework for defining a consistent process to identify potential threats, adapting and integrating the operational use of existing guidelines, and increasing flexibility to deal with unanticipated threats. These include support for assessing the integration of cascading effects and interdependencies (ISO 22301:2019) and resilience 'maturity levels' in an organisation or facility (BS 65000:2014, ISO 22316:2017).

Moreover, the US National Fire Protection Association (2019) highlights further the need to evaluate the possible cascading impacts of 'regional, national or international incidents', considering the potential combinations of frequency, severity and cascading impacts for different categories of threats. Continuity management could then inform some key questions for self-assessment derived from the existing guidelines on the subject (UNISDR, 2012; Pescaroli et al., 2017). Using that as a basis, the following checklist may be considered by practitioners and strategic trainers.

- How much has the planning and construction of the EMFIs taken into account current and future disaster risk in the area? Are there any critical nodes for command and control, or emergency relief logistics, that lie in high-risk areas?
- Is vulnerability assessment of the facility conducted and updated, and have mitigation measures been implemented considering the possibility of an escalating crisis? Has planning integrated forward-

looking tools and wider impact assessment methods that are suitable for defining cascading effects and multiple infrastructure failures? What training tools could need implementation?

- Has a gap analysis or resilience assessment been conducted in order to consider the ability of the EMFIs to remain operational during an extended energy, transportation or telecommunications failure? Is it updated and considered to be a realistic worst-case scenario with compounding dynamics (e.g. a power failure during cold weather)? Does the organisation have provisions for emergency power and communication?
- What are the technological lifelines that the organisation has to ensure to remain operational? Is there a 'plan B' for short-, medium- and long-term disruptions? Have backup solutions for essential information and communication technology tools been arranged and alternative procedures been developed?

5.2 Documentation in the European Union

Given the emphasis on Europe in this report, a short overview of the key documentation produced by the European Commission is warranted. Scenario building can be facilitated using the documents that explain and list the expected impacts of extreme climate change on critical infrastructure, and the concomitant implications for society (European Commission, 2013a). Although this approach has limitations, it can provide a practical overview of compounding dynamics upon which to develop scenarios and understand cross-sectoral disruptions. Similarly, in 2013 the European Commission (2013b) provided a roadmap for the implementation of the European programme on critical infrastructure protection, with the inclusion of cross-sectoral interdependencies that could be used as a basis for understanding cascading effects.

Although this documentation needs better integration between the legislative tools, for example between the European Floods Directive (EU, 2007) and the Council Directive 2008/114/EC (EU, 2008) — identification and designation of European critical infrastructures and assessment of the need to improve their protection (Nones and Pescaroli, 2016), the process is constantly evolving. With respect to cascading events, the capacity to communicate and coordinate efforts needs to be increased, while new strategies for vulnerability assessment need to be put in place. At the EU level it can be assumed that there are contextual differences between national capacities, local realities and organisations present in the same jurisdiction. These differences must be recognised and considered at the strategic level.

5.3. United Nations guidelines and checklists

A wider spectrum of actions can be derived from the documentation produced by international bodies. The SFDRR contains some specific references to emergency facilities. It recommends increasing the resilience of critical infrastructure such as hospitals, and introducing practices of safe design, standardisation, periodic maintenance and sociotechnological impact assessment (UNISDR, 2015). The SFDRR stems from the evolution of multidisciplinary and practice-oriented research that integrates climate change adaptation into planning and policy design, and promotes emergency planning oriented towards prevention (Aitsi- Selmi et al., 2016).

It can be noted that some of the observations on emergency facilities were based upon other practices, such as those developed by the World Health Organization and Public Health England (2013). These recommendations underline the need to build safe hospitals and to ensure that health facilities remain operational in emergencies. Planning, training, exercising and developing a surge capacity are essential activities. They highlight the need to plan for multisectoral disruption in order to assure the continuity of health services (World Health Organization and Public Health England 2013). Some complementary guidelines have been developed under the Words into Action initiative, which has been promoted by UNISDR in order to support the national implementation of the SFDRR. These provide information on the underlying drivers of risk including the different types of disasters that could occur (UNISDR, 2017). An essential asset to consider is national disaster risk assessments, which provide the means by which the vulnerability of emergency facilities is understood, and standards of preparedness are created by means of investment and exercises (UNISDR, 2017).

For example, if the risk register defines a possible event as having moderate likelihood but major impact, contingency planning will have to consider realistically possible disruption over a broad scale. At the local level, local disaster risk reduction and resilience strategies have to identify the essential aspects of risk scenarios. They must update information on critical infrastructure, the potential impacts of hazards, and possible cascading effects that could reduce local capacity (UNDRR, 2019). Further consideration has to be given to the strategic dimension of interagency coordination and protocols, which in many cases can lead to the fragmentation of preparedness and organisational standards. For example, there may be gaps in the process of informing the public and deciding what information to provide in case of technological disruption, such as power failure, and how this provision of information can be extended to other urban and rural areas.

The case studies reported in this chapter illustrate the need to plan for operational continuity and organisational resilience in order to assure that lifelines can be restored as fast as possible. Further guidance can be found in practical handbooks for local government and professional practice (UNISDR, 2012; Linkov and Fox-Lent, 2016; Pescaroli et al., 2017).

Future impacts of climate change should be considered in order to establish early warning and monitoring systems, defining, ex ante, the decision thresholds that could influence crisis management agencies and coping strategies (UNISDR, 2012, UNDRR, 2019). Finally, the location of emergency facilities should be reassessed in relation to changing vulnerability and hazards. Minimum standards of resilience should ensure that supply routes and lifelines are identified in order to prioritise the maintenance of emergency facilities and the delivery of emergency relief, for both events triggered by natural hazards and those triggered by technological scenarios (UNISDR, 2012; Pescaroli et al., 2018).

6 Conclusions and key messages

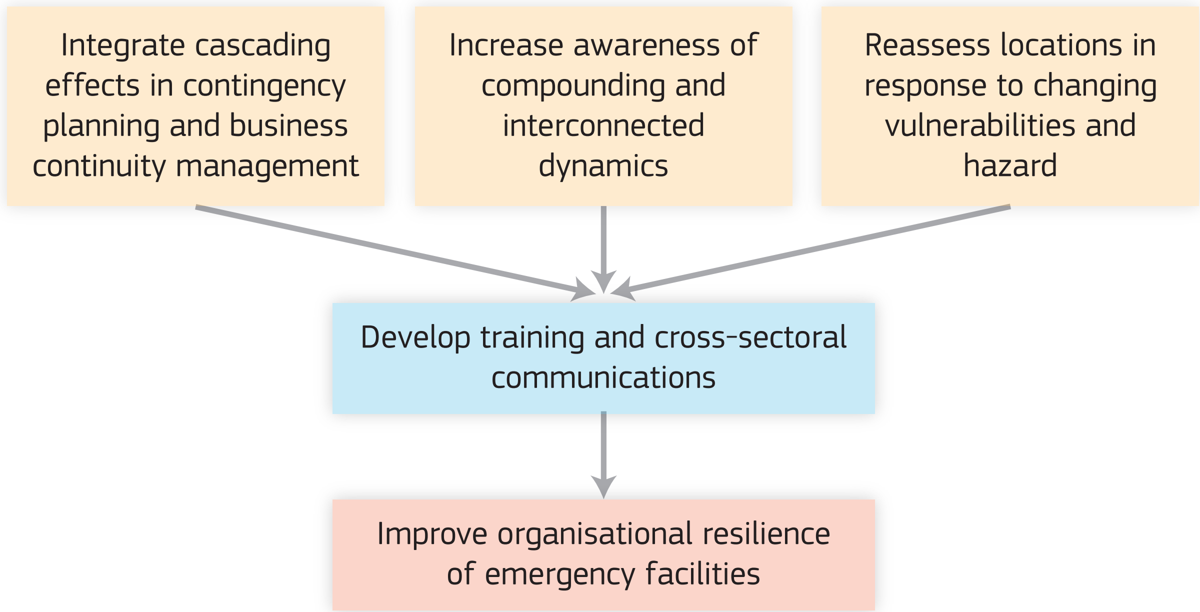
The next steps for improving the resilience and operational continuity of emergency facilities and infrastructure include efforts to improve multi-stakeholder coordination and impact assessment.

Maintaining the operational capacity of emergency facilities and infrastructure is at the centre of this subchapter. The adoption and implementation of the SFDRR and the Words into Action guidelines are essential measures designed to increase the resilience of emergency facilities while at the same time reducing future disaster risk (UNISDR, 2015, 2017;UNDRR 2019). However, the theory and the case studies provided here highlighted that many challenges for the application of these concepts still exist in practice.

First, there may be a structural issue of coordination, communication and information sharing in the management of EMFIs, and this could undermine the improvement of training and exercising for complex scenarios.

This is particularly true in the case of cross-sectoral failures, in which emergency facilities are disrupted by the cascading effects triggered in other sectors, such as electricity. The recent global crises associated with COVID-19 highlighted even further the need to see EMFIs as the nerve centre of our social functions, developing a collaborative and inclusive process to assure their operational capacity.

Figure 4. *Steps for improving organisational resilience of emergency facilities* ***Source****: Authors*



Cross-cutting challenges

Differences in the language used by academics, policymakers and practitioners could cause problems. It is realistic to believe that they could be overcome by collaboration in the medium term, so that counterparts learn to know each other's point of view, creating both trust and knowledge exchange. The existence of different timelines for policymaking, utility management and research may need the development of a focused research project and impact-oriented studies. In conclusion, it is evident that dynamics (such as budget cuts) affect both academics and practitioners by limiting the resources available.

This element can potentially disrupt emergency services and represents a situation in which positive changes, in terms of proactive collaboration, may be less limited by institutional and administrative barriers. New steps to assure the organisational resilience of emergency facilities are essential to prevent the escalation of future crises, and the collaboration of all the actors involved in emergency planning and management is necessary to mitigate complex scenarios.

Policymakers

Account must be taken of the need for further development of conventions on multi-stakeholder collaborations to support a systematic exchange of information, expertise and results. The identification of internal and external interdependencies suggested in new continuity management standards such as ISO 22301:2019 and NFPA 2019/1600 could be the first step in this process. However, new steps are needed in terms of legislation and policies to support the development of a holistic collaborative framework and introduce better accountability and compliance requirements. Some open questions remain, associated with the quantification of cascading impacts triggered by the disruptions of EMFIs. At the time of writing, it is not possible to access any quantitative information on losses and damages that could have been avoided if EMFIs had been completely efficient. These data could be used to develop some better cost–benefit analyses to support decision-makers. Clearly, this approach is merely a first step in a longer process of improvement and evolution that should involve EU legislation and policies.

Practitioners

Possible mitigation for this issue includes the adoption of standardised practices for creating organisational resilience and understand internal vulnerabilities (ISO 22316:2017, 22301:2019; NFPA 2019/1600), while increasing the adoption of measures in line with the scenarios proposed in the updated versions of national risk registers (UNDRR, 2019). Figure 4 shows the main steps needed to improve the organisational resilience of EMFIs in the near future by actively involving training and cross-sectoral communication between stakeholders. In the assessment process the functionality of vital services must involve multiple dimensions, such as operations, structure, planning and resources. These have different potentials to become useful tools in practice. They have been extensively evaluated, for example in the Intergovernmental Risk Governance Council's Resource Guide on Resilience (Linkov and Fox-Lent, 2016). Furthermore, scenario building should integrate cascading effects and interconnected dynamics in order to understand the carrying capacity of EMFIs during technological failures and complex events (NFPA 2019/1600). The integration of these aspects in practice requires the development of further collaborations with academia.

Scientists

Many aspects of this assessment process represent a fine opportunity for an active role of scientists in supporting practitioners and decision makers. For example, new collaborations can be developed in order to understand gaps in preparedness for cascading events, as well as to analyse structural and non-structural vulnerabilities to multiple threats. Moreover, scientists could actively support the development of new scenarios and strategic foresight to be used in training activities, as has already been done in the field (e.g. Alexander, 2016; Pescaroli et al., 2017).

Citizens

The role of individual citizens is another element that can be explored to improve the status quo. For example, the literature recommends defining what to communicate and how to do it (Alexander, 2016; Lindell et al., 2007), but there is a lack of understanding of what procedures would be most useful if emergency facilities were disrupted. In line with the SFDRR (UNISDR, 2015), it could be useful to develop better involvement with local communities and stakeholders. Indeed, civil society could represent an essential asset for coordinating emergency efforts, and developing basic training for the population on cascading scenarios could be one of the tools for improving societal resilience (Royal Academy of Engineering, 2016).