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Hospital Energy Resilience

Katerina Vichova and Martin Hromada

Abstract

Many emergencies and crises threaten the whole world. These affect not only the lives, health, and property of citizens but also the subjects and elements of the critical infrastructure itself. Breaking the critical infrastructure system would have a severe impact on the state's security, securing the basic living needs of the population, the health of the people, or the economy of the country. One of the significant sectors of the critical infrastructure is undoubtedly healthcare. It is vital for the health service to be able to perform its function, even in times of crisis. The crisis of naturogenic character ordinarily has the so-called cascade effect, which causes other extraordinary events and crises. An example of this may be windstorm, resulting in a power outage. A significant impact of the power supply outage in healthcare is observed in hospitals. There is currently no assessment tool to set the hospital's readiness for a power outage. The aim of the chapter is to analyze the current state of the crisis preparedness of the hospital.

Keywords: power outage, hospital, energy supply, critical infrastructure, emergency management

1. Introduction

Many extraordinary events and crises threaten the whole world. There were 281 disasters and 61.7 million people were affected by the natural disaster in 2018 in the whole world (based on the International Disaster Database). Next, there were about 1600 storms in 2018. These disasters often cause the power outage. These affect not only the lives, health, and property of citizens but also the subjects and elements of the critical infrastructure itself. Naturogenic or anthropogenic threats could cause it. The aim of each state is to protect its citizens and the necessary infrastructure of the country where systems called critical infrastructure can be considered. Breaking the critical infrastructure system would have a severe impact on the state's security, securing the basic living needs of the population, the health of the people, or the economy of the country. However, the critical infrastructure system must be viewed comprehensively [1].

There are many sectors of the critical infrastructure (see **Figure 1**).

In some cases, the disruption of the critical infrastructure has an impact on the next system. Rinaldi called this as the cascade effects [3]. Next, Rehak examined the cascade effects in the critical infrastructure system [4].

As with any network, a critical infrastructure system has elements with different levels of importance (criticality). The damage, disruption, or failure of an important

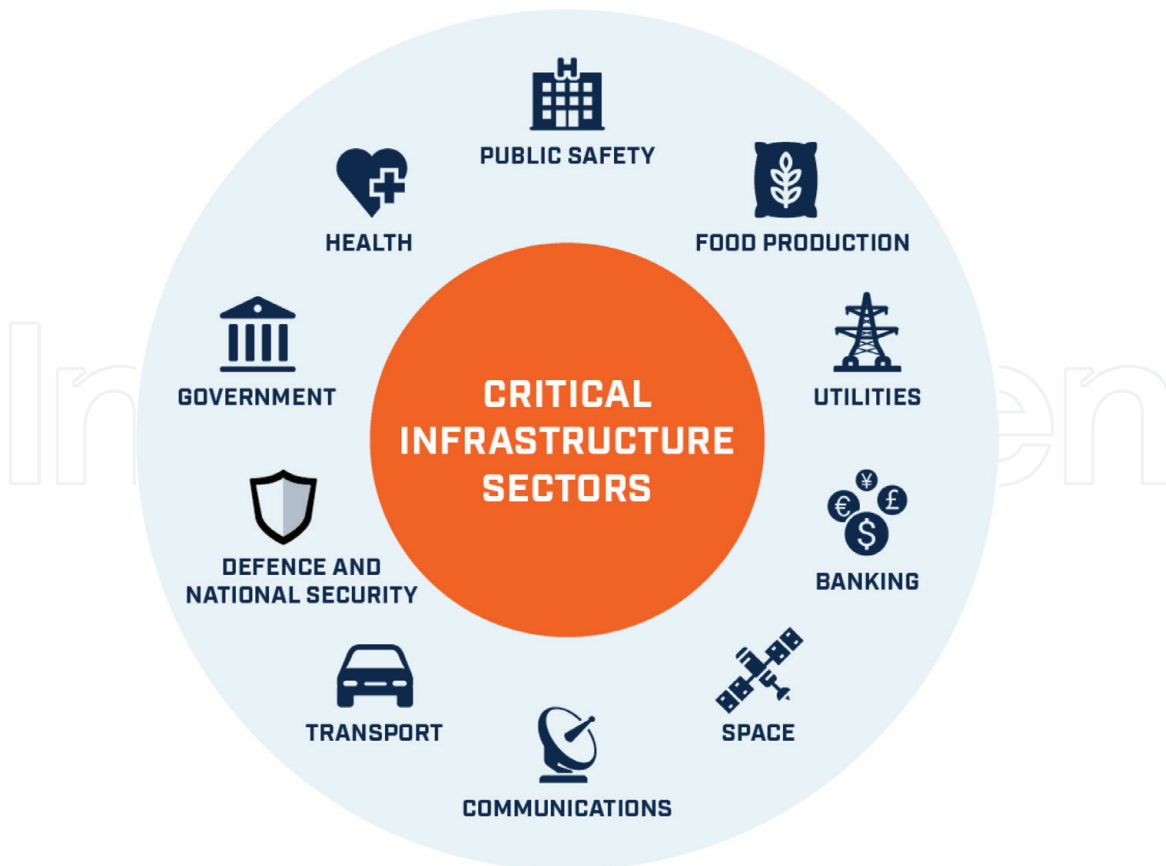


Figure 1. Critical infrastructure sectors [2].

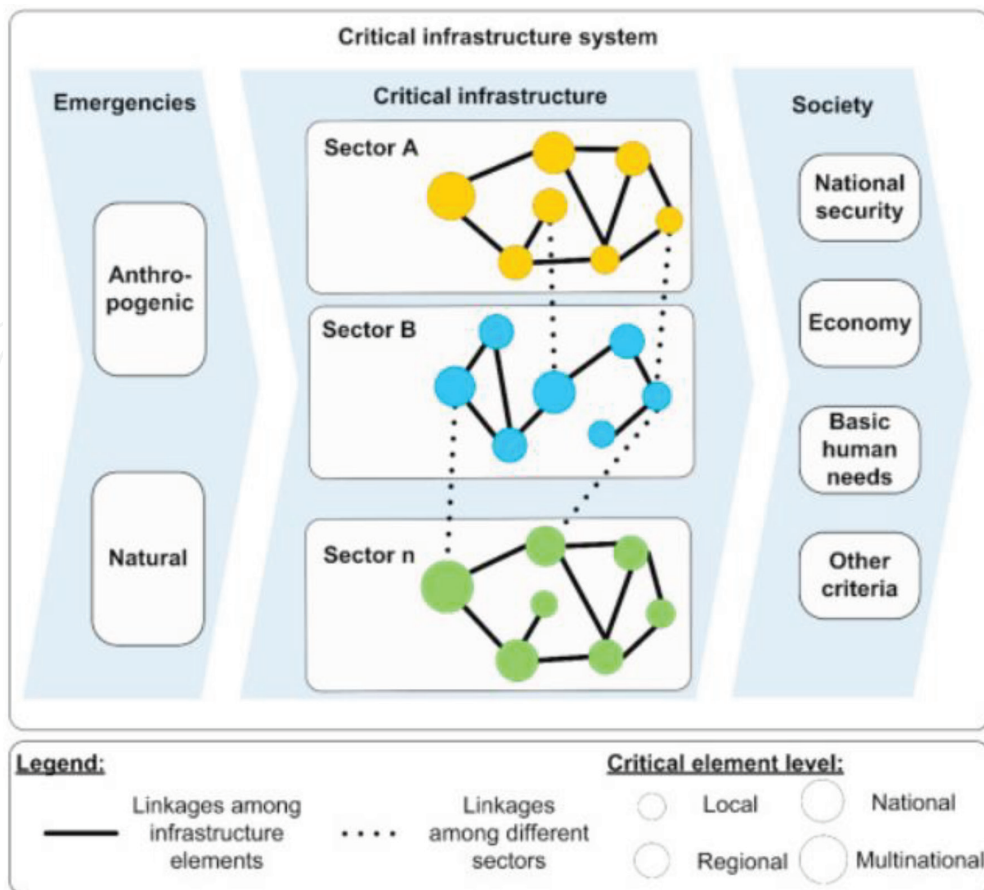


Figure 2. Critical infrastructure system [4].

(critical) element has a more or less serious impact based on the number and character of linkages that define its level of effect, dependence, or interdependence [4].

The crisis of naturogenic character ordinarily has which causes other emergency — it could be called cascade effect (see **Figure 2**). An example of this may be windstorm, resulting in a power outage. One of the most critical risks for modern science is a large scale power system blackout [5]. Over the decade, electricity plays a major role in the modern day life. Even a momentary power outage can create chaos, revenue loss, and loss of life [6].

It is clear from the list of sectoral criteria that the health sector is also essential for maintaining the state's security and maintaining the functioning of the country. Here, it is necessary to mention the interconnection of critical infrastructure elements. Just breaking the essential element of infrastructure—power outage could result in a cascade effect, namely healthcare.

The aim of the chapter is to analyze the current state of the crisis preparedness of the hospital.

2. Power outage

As has already been noted, naturogenic emergencies and crises may also result in further indications. One of them is a power outage (in some countries we can also find the term blackout). In the Czech Republic, this threat is frequently described as the failure of large-scale electricity supplies, but sometimes we can also find the term “blackout” [7, 8]. In English literature, we can find a replacement for the term “power outage”. The term blackout is defined as a total power outage in a large area [9]. Furthermore, this term refers to the moment when the balance between the production and consumption of electricity has been violated, and the security of supply is undermined [7].

Power outage affects not only the lives of people but also the operation of the whole state, especially the economic development of the affected area. The particular feature of the blackout is that the secondary consequences of the outage are many times greater than the effects on the plants for the production, transmission, and distribution of electricity. The cause of this is dominoes that arise from the interconnection of the entire critical infrastructure [8].

It is a predictable factor that causes disturbances on the transmission or distribution system. In this case, the account is also taken of historical events where a power outage was caused mainly by the wind storm. This event could create a cascade effect when one cause gradually raises a series of related events.

Also, the failure of the power supply may be caused by a technical fault. Disturbances, such as transformer fire, can occur both at the power generation points and directly in the transmission and distribution system. If a combination of several serious faults occurs, a significant power outage may occur.

Among other causes, we could include the human factor. In case of concurrence of several negative influences, dispatchers may erroneously assess the situation that may result in a significant power outage. Such conditions are prevented mainly by professionally qualified service personnel and by creating a comprehensive set of safety rules. From the analysis of available data, it is clear that even a terrorist attack may also be a cause of failure. The attack could be made directly, for example, by the destruction of the transformer station, or it could be done through information networks, called the cyberattack.

Finally, there may also be a significant over-flow of energy from foreign grids. An example may be the transport of electricity from power plants in northern Germany to the sampling centers in the southern parts of Germany through the

transmission system of the Czech Republic. In the event of a sudden increase in electricity production, along downtime could occur.

Act No. 458/2000 Coll., on business conditions and the execution of state administration in the energy sector and on the amendment of some laws (Energy Act), indicates that an emergency may occur in the electricity grid. A state of emergency means a condition resulting from natural disasters; measures taken by the state authorities for an emergency, a state of state threat, or a state of war; accidents or cumulation of failures in electricity generation, transmission, and distribution facilities; smog situations according to special regulations; terrorist attack; unbalanced electricity grid balances or parts thereof; transmission of a fault from a foreign electricity system; when physical or personal safety is at risk and causes significant and sudden electricity shortages or threats to the integrity of the power system, its security, and reliability in the whole territory of the state, the significant territory or part thereof [10].

Although the company has relied on electricity infrastructure since the early twentieth century, the increasing complexity of infrastructure and its interdependence with other infrastructures such as information and communication technologies makes it more vulnerable. Even if the electricity supply outage is rare, it will occur more frequently and for a more extended period (the result of naturogenic crisis caused by climate change) [11].

Due to the sophisticated security system, the most likely cause of a major power outage is overlapping several primary reasons at one time. Due to the cause of the power supply outage, the rate of renewal of supplies also develops. If there is marked physical damage to the infrastructure, the recovery time will be proportional to the extent of the damage—in days to weeks [12].

Based on the fact that today's world is dependent on electricity, which is used in all areas of life, the power supply outage may have significant consequences. It could, therefore, be assumed that the power outage will occur in all areas—health, public transport, supply, restriction, or interruption of drinking water, gas, heat, outages of mobile operators, Internet network failure, public safety, etc.

2.1 History of the power outage in the world

The whole world is struggling with power outages that last for a variety of periods, affecting states or parts of them, and hence different populations. Power outages are widespread in Asia; however, the low level of robustness of the energy network is taken into account. Nevertheless, even developed countries do not avoid these events, as a cascading effect of an ever increasing number of emergencies and crises.

The northeastern portion of the US and the southeastern part of Canada hit an extensive power outage in 2003. In total, about 50 million people were affected, and in some places, a state of emergency was declared. The cause of this outage was the interconnected problems mentioned. It is said to have been the neglect of maintenance of vegetation along backbone power lines, the inability to detect network problems and communication with neighboring power systems, inadequate training of dispatchers, and lack of backup systems.

This power outage resulted in several events. It was a failure of the mobile telephone network due to overloading by a massive number of calls and a lack of energy to charge mobile phones. Mobile network reliability proved to be quite low and unreliable in a crisis. In some places, there has been a drop in pressure in the water pipes, and there is a risk of the entry of dangerous substances and organisms into the water. The electrified lines were out of service throughout the downtime in the USA. In chemical operation, 140 kg of poisonous vinyl chloride was leaked into the river, and some had to be hospitalized. The mines were trapped by miners who evacuated after the resumption of electricity supplies.

The date of the power outage	Country	Cause	Inhabitants without electricity (millions)
31/03/2015	Turkey	The shutdown of two power plants and simultaneous maintenance on transmission lines (not confirmed)	70
26/10/2012	Brazil	Fire in the substation	53
30/07/2012–31/07/2012	India	The gap between production and dynamically growing consumption (overloaded lines), which has been momentarily exacerbated by unfavorable climatic conditions	670
08/09/2011	USA and Mexico	Operator error and consequent failure of the high voltage line	3
11/03/2011	Japan	The decommissioning of nuclear power plants, after their damage to the tsunami caused by the earthquake	4.4
28/1/2008	China	The snowstorm destroyed the very high voltage line	30
11/11/2009	Brazil, Paraguay, and Uruguay	Short circuit of three transformers due to heavy rains	60
18/08/2005	Indonesia (Java Islands and Bali)	Multiple EC failure to eliminate 2700 MW of the power	100
27/09/2003–28/09/2003	Italy	Storm	56
14/8/2003	USA and Canada	Short branches of the tree and consequently a weak solution to these initiation faults	50
20/02/1998–27/03/1998	New Zealand	Repeated failures on the high voltage cables	1

Table 1.
History of the power outage in the world [author].

In the same year, Italy and Switzerland suffered a significant power outage. It affected about 56 million people. Again, these were cumulative causes that resulted in a significant power outage. The backbone line between Switzerland and Italy was heavily overloaded, and there was a shortage of surrounding vegetation. The operators had 10–15 min to solve this situation, which they could not solve. After the failure of the second backbone line, there was a cascade effect and the interruption of all other lines [7].

The following table shows the history of the significant power outage in the whole world (see **Table 1**).

Table 1 shows the significant power outage from 1998 to 2015. As can be seen, the largest population without electricity was in 2012 in India. This outage hit 670 million of the inhabitants.

2.2 History of the power outage in the Czech Republic

Even though the Czech Republic is using efficient instruments of crisis management in the electricity sector, its requirement ever is taken into account that this event may occur. After the devastating storm Kyrill in 2007 and Emma in 2008, we

must admit that [13]. In this respect, critical infrastructure equipment is a back-up powerhouse with its fuel supply, which is capable of covering the consumption of essential offices, hospitals, etc. [7]. Hospitals are a critical infrastructure sector where it is necessary to operate as soon as possible restored.

The failure to supply electricity of the same magnitude as the one mentioned in the world has not yet been recorded in the Czech Republic. There were only local power outages or power line interruptions. These are several, frequently caused by extraordinary events and crises of a natural character.

On the verge of the power outage was the power industry declared an emergency on 24 July 2006 in the Czech Republic. It was not a typical power outage regarding a fatal impact on the consumer—no households have been interrupted by the supply of electricity in the Czech Republic. However, due to the announced regulatory levels, large consumers have had to limit their collection [14]. The reason for this outage was the previous rupture between the Hradec and Etzenricht substation. This line was replaced, but on July 24, when the substation was re-connected to an unexpected outage at the Diviča substation, this increased the demand from the Czech Republic to Austria. The cascade effect then caused further outages [14].

Another reported power outage, this time with an impact on the population, had a cause in the Kyrill storm, which was moved across Western and Central Europe and also hit the Czech Republic in 2007. The CEZ Energy Group has declared a state of emergency in the Czech Republic as a result of this storm. Due to the consequences of the wind turbine, 27 percent of CEZ Group supply points were found without electricity, which includes more than a million households. This condition was caused mainly by the fall of trees and branches into power line, thunderstorm, and other weather influences [15].

Emma was struck by Europe and the Czech Republic a year later. Again, it caused the fall of trees to power lines, which resulted in up to 920,000 households without electricity. The Herwart storm came as a result of the fall of trees to power lines in the Czech Republic 10 years after Emma's. CEZ Group has declared a calamity situation in eight regions. Without electricity, there were 500,000 subscribers. CEZ Group registered approximately 14,000 households without electricity [16].

There was also an intense storm of Fabianne in 2018. This storm caused power outages, primarily because of the trees grabbed on the line. There were 160,000 households without electricity.

From the history of large-scale power supply outages, it can be observed that the greatest cascade effects caused by naturogenic phenomena have the greatest effect on the outage.

2.3 Power outage in the hospitals

This part of the chapter deals with the history of power supply outages with impact toward the hospitals. A list of selected events according to the time horizon in selected parts of the world is presented.

An earthquake hit the islands of Lombok and Bali in Asia in July and August 2018. During this disaster, 98 people died. The earthquake intensity was on the seventh Richter scale. This catastrophe has caused landslides and as a consequence of the downstream cascade effect, power outage [17]. The main hospital in Tanjung in the north was critically damaged and evacuated. Employees prepared a provisional hospital—about 30 beds were in the shade of the trees and in the tent on the playground to have a place to treat the wounded. Other hospitals were overcrowded, and some patients were treated in car parks [18].

Tropical storm Leslie hit Europe in 2018. This storm hit mainly the southern part of Europe. The most affected were Portugal, France, Spain, and the island state of Mallorca. The storm caused a flash flood in these states. The hospitals were flooded, and thousands of people in France were evacuated. A similar situation was also in Portugal, which was also hit by flash floods [19].

Another was the Irma Hurricane in the US. It was the strongest hurricane in the Atlantic in recorded history. The storm arrived on the Barbuda coast in September 2017. Its wind speed was 185 miles per hour for 37 hours. More than 10 million people have stayed in Florida without electricity. More than 5 million Florida residents were evacuated [20]. Some hospitals were affected by Hurricane Irma. Hospital staff decided to dismiss patients who were able to be in home care. Other patients had to be evacuated to other hospitals. In some hospitals, urgent income has been interrupted.

Hurricane Sandy arrived on the US coast in October 2012. It was a post-tropical cyclone. The Hurricane began as a tropical wave in the Caribbean and quickly, in just 6 hours, turned into a tropical storm. It turned into a hurricane during October 24th. The total deaths reached 285, including 125 deaths in the United States. Hurricane caused damage of \$ 62 billion and \$ 315 million in the Caribbean. More than 7.5 million people were without electricity [21].

Hurricane Sandy caused floods to hit hospitals, causing power outages in New York. Five hospitals were forced to evacuate patients. The evacuation was also required due to power outages. Other hospitals were evacuated due to the flood of cellars. The aggregates that were placed here ceased to work.

These events are just a selection of some naturogenic disasters that have had an impact on the hospitals. A naturogenic disaster did not cause the following power outage. It was a power outage that lasted for 6 weeks in 1998. The city of Auckland was hit in New Zealand. A technical failure caused this outage. The initial assumptions of the downtime were for 1 week and then the estimates of the energy company's employees were specified per month. The number of banking data centers, stock exchanges, central city offices, customs and immigration, inland revenue, internal affairs, social care, Auckland City Council, central police, significant hospitals, University campus and technical institute, television and radio stations, hotels, and more was affected. Although many of these buildings have generators, various switching failures have caused problems and subsequent outages. Some institutions have tackled a power failure by purchasing aggregates from Australia or Poland [22].

The Czech Republic has not met the failure of electricity supply with the impact to the hospitals of such magnitude.

3. Crisis management and healthcare

As mentioned above, the security threats to the Czech Republic, but also the whole world have the character of naturogenic or anthropogenic. These may result in the power outage.

Act No. 458/2000 Coll. regulates energy in the crisis (Energy Act) and the decrees of the Ministry of Industry and Trade (Decree No. 80/2010 Coll., Decree No. 344/2012 Coll., Decree No. 225/2001 Coll.). Electricity for the population will be delivered according to the appropriate level of regulation, tripping, and frequency plan based on the specific situation [10].

The Ministry of Health of the Czech Republic is responsible for crisis management in health care. To that purpose, a crisis preparedness workplace is set up [23].

The Charter of Fundamental Rights and Freedoms states that everyone has the right to health protection. Citizens have the right to free healthcare and medical aid by public (health) insurance under the conditions laid down by law [24].

The Ministry of Health of the Czech Republic states that its role in crisis management is to ensure framework conditions for the provision of health care at the crisis by creating and enforcing state health policy [25].

Crisis preparedness in the health sector is defined as the ability of health care providers, and health care facilities to provide essential health care to the population locally relevant to administrative unit for emergency and crisis in the continuity of medical policy for the provision of health care by qualified personnel [25].

In the introduction of the chapter, the impact of crises on state security and threats to its infrastructures was mentioned. This subchapter describes crisis management in the hospitals.

Healthcare facilities are spaces for the provision of health services [26]. However, this concept includes not only hospitals but also therapeutic institutions, spa health facilities, general practitioners, and others.

For this research, a healthcare facility—a hospital was selected. A hospital is a medical facility licensed to provide health care, has many beds, an organized medical team of the requisite qualification, and offers continuous nursing services. Hospitals are divided by the number of beds to small (up to 700 beds) and large. They can also be classified by type of ownership into hospitals owned and administered by the state, public hospitals administered by regions, towns and municipalities, private hospitals or nonprofit hospitals, and hospitals based on a business principle [27].

The term healthcare is also defined, which can be considered a multidisciplinary field. Healthcare is modern medicine that represents a complex process that accumulates human knowledge from a wide range of disciplines, not just science, but also technical and social sciences. The collected data and acquired knowledge are thus used both for theoretical and scientific purposes, that is, for the development of the discipline as an academic discipline, as well as for the practical decisions of both political and managerial disciplines [28]. From the above definitions of health care, it is evident that there are also other disciplines, one of which is also computer science. It interferes with healthcare not only in the form of electronic patient cards but primarily as a national health register. Nowadays, information support for crisis management is also being used. The objective of information support is to simplify, streamline, and accelerate crisis management with the help of information systems.

As has been mentioned, healthcare is a multidisciplinary field, which also involves other interests. This work attempts to connect three branches, namely health, informatics, and crisis management.

4. Critical infrastructure and healthcare

As mentioned above, the objective of each state is to protect its citizens and the basic infrastructures of the country where systems called critical infrastructure can be considered. Disruption of a critical infrastructure system would have a significant impact on state security, the security of the basic living needs of the population, the health of people, or the state's economy. The Czech Republic defines industry criteria for identifying industries, sub-sectors, and critical infrastructure elements. Healthcare is also one of the critical sectors of critical infrastructure.

With the increasing insertion of new information and communication technologies into all areas of life, resource consumption, and the maintenance of living standards, new threats arise not only for individuals but also for the economy, the

state, and society. Threats can arise from not only organized groups and terrorist and criminal organizations, but also manifestations of hostilities of countries, natural disasters, or competing struggles for necessary raw materials. Specific area of society's life more dependent on, critically reliant on another area, the more severely the infrastructure sector is causing the functionality or limitation of the feature of a particular sector [29]. Government Regulation No. 432/2010 Coll. criteria for identifying critical infrastructure elements were introduced in the Czech Republic. This government regulation divides the criteria into cross-cutting and sectoral. Sectoral criteria are defined by the following sectors:

- energy,
- water,
- food and agriculture,
- health,
- transport,
- communication and information systems,
- financial market and currency,
- emergency services, and
- public administration [30].

It is clear from the list of sectoral criteria that the health sector is also essential for maintaining the state's security and maintaining the state's functionality. It should be noted that this is a hospital with a total number of acute beds of at least 2500. However, no condition is fulfilled by any hospital in the Czech Republic.

Because of the need to cope with the crisis in hospitals, it is essential that hospital emergency care must be implemented. In this case, it should be noted that the critical infrastructure referred to is directed to healthcare. In healthcare, as in other areas, eight critical areas are defined (see **Table 2**). In healthcare, they have their specific features and commodities. All of them are essential for healthcare, and their activities are under crisis management [31].

1.	Electricity, gas, and fuel
2.	Supply—drugs, lingerie, food, and water
3.	IT—medical documentation, internal contact, and contact with superiors and other external organizational units
4.	Management
5.	Transport of persons and materials—medical and supportive
6.	Insurance and finance—sharing personnel, health service, and costs
7.	Special substances—medicines, artificial nutrition, and special and basic medical supplies

Table 2.
Critical area of the hospital [31].

5. Supply of healthcare facilities at the time of power outage

Czech Standard ČSN 33 2140 entered into force on electrical wiring in rooms for medical purposes in 1987. This ČSN was valid until 2015. Subsequently, ČSN 33 2000-7-710 was introduced for low-voltage electrical installations; part 7-710 deals with special-purpose devices in particular premises—medical areas. It should be noted that this current ČSN is valid for newly built medical facilities.

For medical premises, a power source must be installed which, in the event of a faulty mains supply, for a specified period and at a predetermined switch-over time, provides power to devices divided by a power source with different switching times.

Power supplies with a switching time of up to 0.5 s including—in the event of a voltage failure on one or more phase wires in a switchboard, a power supply must be used to provide power to illumination of operating tables and another necessary lighting, such as endoscopes, at least after 3 h, and the resumption of voltage must be within 0.5 s [32].

Power supplies with a switching time of up to 15 s—safety lighting and other devices (see below) must be connected within 15 s to a power source capable of supplying power for at least 24 h when the voltage on one or more mains power supply mains security purposes will be reduced to less than 90% of the nominal value for more than 3 s [32].

Power supplies with a switching time of more than 15 s—power supplies for other electrical equipment of medical equipment that do not meet the requirements listed above and are required for health services may be connected to the power supply automatically or manually. This power supply must be capable of delivering power for at least 24 h. These electrical devices can be sterilizing devices; building equipment such as heating or air conditioning, ventilation, building, and waste disposal facilities; cooling device; kitchen furnishings; and battery chargers [32].

Lightning escape routes are considered as safety lighting; illumination of exit signs; all wiring (including switchboards with main switchboards) of rooms with safety and additional safety sources; rooms where essential services are provided; group 1 healthcare facilities; and group 2 medical facilities [32].

Among other devices, we can include selected fire lifts; ventilation systems for smoke extraction; people search systems; medical electrical appliances used in group 2 medical areas which are intended for surgical or other applications of vital importance; electrical devices for the delivery of medical gases, including compressed air, vacuum supply, and anesthetic gas discharge system, as well as their monitoring devices; and fire detection, fire alarm, and fire extinguishing systems.

This standard provides a classification of safety circuits for healthcare facilities (see **Table 3**).

Class	Interruption
Class 0—without interruption	Power is provided automatically without interruption
Class 0.15—very short interruption	Power supply automatically up to 0.15 s
Class 0.5—short interruption	Power supply automatically up to 0.5 s
Class 5—normal interruption	Power supply automatically up to 5 s
Class 15—middle interruption	Power supply automatically up to 15 s
Class >15—long interruption	Power is automatically provided for more than 15 s

Table 3.
Classification for the interruption [32].

Medical area	Group			Class	
	0	1	2	≤0.5 s	>0.5 s ≤ 15 s
Massage room	X	X			X
Bed room		X			X
The birth hall		X	X		X
ECG, EEG, and EHG room		X			X
Endoscopy		X	X		X
Investigation room or nursing room		X	X		X
Urology		X	X		X
Radiological room		X			X
Hydrotherapy		X			X
Physiotherapy		X			X
Anesthesia			X X		X
Operating room			X X		X
Operational preparation room			X X		X
Operational gypsum room			X X		X
Postoperative room			X X		X
Catheterization room			X X		X
Intensive care room			X X		X
Angiography			X X		X
Hemodialysis		X			X
Magnetic resonance		X X	X		X
Nuclear medicine		X			X
Room for premature babies			X X		X
Intermediate care unit			X X		X

Table 4.
 Medical room and their classification [32].

The classification of importance may vary for each site. In this case, the highest safety requirement obligation is taken. It is possible to refer to the following table (Annex B of the ČSN), which contains the classification of healthcare facilities regarding safety circuits (see **Table 4**).

Table 4 shows the classification of healthcare facilities by group. The author considers the operating rooms, the postoperative room, intensive care units, the delivery room, and the premise for premature babies to be the essential premises regarding electricity supply.

Hospitals are among healthcare facilities whose rapid and efficient services play an essential role in reducing disaster mortality rates [33]. A critical part of crisis management is the search for and mitigation of the risks to the population, depending on assistance and care in the healthcare facilities [34].

Therefore, hospitals should be designed and built to be able to deal effectively with all kinds of crises [35]. One of the problems of the World Health Organization (WHO) is the disaster preparedness of the hospitals [36]. There is still no standard and valid tool for assessing disaster preparedness in the hospitals [37]. Disaster managers need accurate and useful tools to assess disaster preparedness for

hospitals. However, there is no standardized and comprehensive instrument for this purpose [38]. Based on the authors' quotations and the analysis carried out, it can be stated that there is still no evaluation system to determine the hospital's preparedness for the crisis.

6. Methodology

In this chapter, four scientific methods were used. Firstly, it was the analysis, which we used for the analysis of the hospitals. Secondly, the method comparison was used, which compares the results from the analysis. Thirdly, the induction method was used, where this method serves to examine the fact of creating a hypothesis from the points obtained. Finally, the heuristic analysis of the preparedness was used.

The heuristic analysis of the preparedness was developed for the evaluation of the hospitals. Based on this assessment, we will get an accurate idea of the weaknesses and strengths of the assessed hospitals.

This analysis was divided into four categories. The hospitals were assessed from the point of view—emergency water supply, emergency food supply, emergency energy supply, and other emergency supply.

Emergency power supply—this category evaluates the preparedness of the hospitals for emergency energy supplies—the ownership of energy supply replacement units. However, these aggregates are fuel-dependent, and it is, therefore, necessary to assess fuel supply to the hospital. It deals with the area of contractual fuelling, its gas station, etc.

Based on the above analysis, an assessment was performed using Eq. (1):

$$HP = \frac{(R + H)}{2 \times H} \times 100\% \quad (1)$$

where HP is hospital preparedness, R is sum of results (obtained points), and H is the number of assessed heuristics.

The evaluation methodology consisted in assigning a response to each question answered in the form of valuation from a predefined set of values (−1 = does not agree, 1 = agree; 0 = partly agree, and blank field if the problem is not relevant).

7. Results

This part of the chapter is focused on assessing the crisis preparedness of the hospitals in the area of emergency energy supply.

The assessment method was proposed—heuristic analysis of the preparedness. This analysis was used for assessing 13 hospitals in the Czech Republic. The Czech Republic is divided into 14 regions. Each region has a different number of hospitals. As a rule, each region has one faculty hospital. However, there are exceptions; for example, the Zlín Region does not have a faculty hospital. There is only a regional hospital. There are also district hospitals, private hospitals, and specialized hospitals. The evaluated hospitals were from five regions in the Czech Republic. Based on the mentioned introduction of this paper, the focus is on emergency energy supply. The following figure shows the results of the 13 hospitals (see **Figure 3**).

Figure 3 shows the emergency energy supply of the hospitals in the Czech Republic. There is a differentiation of the emergency energy supply of the hospitals. As can be seen, the best-evaluated hospital from the point of view is South Moravian Hospital 1. On the other hand, the worst evaluated hospital is in Central Bohemian Region 1. The type of hospital could cause this differentiation.

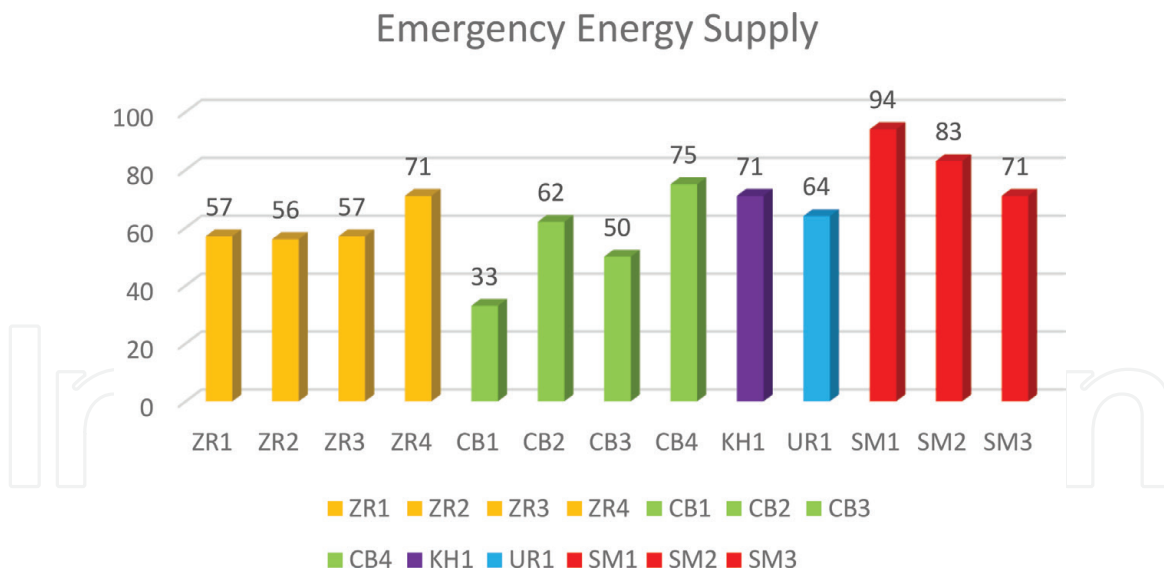


Figure 3.
Emergency energy supply of the hospitals [author].

It was in the readiness of the hospitals to make sure that we saw the supply of electricity and that we saw significant differences. And this fact enabled us to define the primary aim of our research and this chapter.

Each hospital has to deal with the external issue of emergency fuel stocks to address individually. There is currently no valid legislation to ensure this. Some hospitals address this situation through a contractual agreement with fuel suppliers (ČEPRO or other contractors); other hospitals own a gas station where they have sufficient supplies even for a more extended period of the power supply. On the contrary, there are also hospitals that do not solve this problem at all and do not have a contractual agreement with any supplier of fuel. If necessary, they use their ambulances to deliver fuels in barrels from gas stations. Here, however, it is essential to take into account the fact that there may be a power failure in the whole region and there will be no possibility to use all the gas stations.

8. Discussion

In general, healthcare and the provision of health care in hospitals play an essential role for each country. The whole world is threatened by a series of events that may be of naturogenic or anthropogenic character. These events may result in a power outage. The power outage just mentioned has a significant impact on the hospitals. It is therefore crucial that hospitals maintain normal operations even during the crisis.

This chapter deals with hospital energy resilience. The relationship between critical infrastructure-health and power outage is mentioned. This point is discussed regarding nomenclature as well as its history and impact on hospitals. In the past, significant power outage impacts on hospitals could be observed.

Subsequently, a heuristic analysis of the hospital preparedness was carried out. This analysis was used to evaluate the strengths and weaknesses and the subsequent comparison of the evaluated hospitals. A total of 13 hospitals were assessed in the Czech Republic. Based on this analysis, we have concluded this issue. This analysis evaluated the different preparedness of hospitals in the field of emergency energy supply. Each hospital is building a different path to this issue. Therefore, it cannot be said that hospitals will be fully operational in the event of a crisis.

Hospitals belong to the healthcare facilities whose rapid and efficient services can play an essential role in reducing disaster mortality rates [33]. One of the problems of the World Health Organization (WHO) is the disaster preparedness of hospitals [36]. There is still no standard and valid tool for assessing disaster preparedness in hospitals [37]. Disaster managers need accurate and useful tools to assess disaster preparedness for hospitals. However, there is no standardized and comprehensive instrument for this purpose [38]. Crisis management deals with Act No. 240 of 2000 Coll., which does not directly address the disaster preparedness of the hospitals. The exact number of hours that fuel supplies for the aggregate supply must have is not specified. There is only ČSN 33 2000-7-710 that was introduced for low voltage electrical installations; part 7-710 deals with individual purpose devices in particular premises—medical areas. This norm says only until when the electricity must be restored.

Based on the authors' references and the analysis carried out, it can be stated that there is still no evaluation system to determine the hospital's preparedness for the crisis. For these purposes, we propose to introduce a hospital evaluation system.

In the last few decades, science has called the algorithm many practical tools to help solve various computer problems. The algorithm is a set of rules that are typical of specific computer calculations or activities [39].

It is assumed that the use of this system will not only be within the hospital but also by the regional office. We will create a Web portal that will illustrate the hospitals in the region. Each hospital will fill in the data that are required to calculate the length of hospital maintenance (or only selected rooms/circuits) and will be stored in this portal. When the power outage occurs, the expected failure interval will be entered. That will make it clear which hospitals are capable of managing the crisis without having to deliver fuel. Otherwise, the request will be sent to external suppliers or the regional authority (depending on the length of the power supply outage) for the fuel supply. All communication would then take the form of data sentences that would be documented. These data sentences would not only serve to send a request but subsequently to acknowledge the receipt of the application, to submit information about the resources assigned and quantity.

9. Conclusion

The aim of the chapter was to analyze the current state of the crisis preparedness of the hospital. There have been an increasing number of crises not only in the Czech Republic but also in the world in recent years. It has an impact on the critical infrastructure of the country and hence on the lives, health, and property of citizens. Information technologies are increasingly affecting citizens' lives and helping in day-to-day activities, but also in solving the crisis. We can, therefore, see the multidisciplinary nature of this field, which also affects the area of population protection and crisis management.

The central part of the chapter was an assessment of the current state. We are increasingly confronted with threats of naturogenic and anthropogenic character. These events have a direct impact, and in some cases, they also cause cascading effects. An example may be a windswept wind that can cause trees to fall on the power lines and a subsequent power outage. The impact is already on the mentioned critical infrastructure of the country, including, among others, the health sector. In the hospitals, it is necessary to supply electricity in the required range and quality. Based on previous research, it has been found that hospitals' preparedness in the field of emergency energy supply is at a different level. Some hospitals in the Czech Republic are not prepared to face a long-term power outage and rely on help from authorities and other crisis management bodies.

Besides, there is no comprehensive and uniform assessment system to assess the readiness of hospitals to face a crisis—power outage. At the end, a possible way to solve this situation was proposed.

The results of the research will be used as a form of information support in solving the crisis—power supply shortage in hospitals and also in other medical facilities and other facilities. In particular, the use will be linked to the needs of the hospital and the regional authority and any external contractors.

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Conflict of interest

The authors have no conflict of interest.

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