Safety of Constructions from the Point of View of Population Protection in the Context of Industry 4.0 in the Czech Republic

Simona Slivkova *, Lenka Brumarova, Barbora Kluckova, Jiri Pokorny and Katerina Tomanova

Faculty of Safety Engineering, VSB—Technical University of Ostrava, Lumirova 13/630, 700 30 Ostrava, Czech Republic; lenka.brumarova@vsb.cz (L.B.); barbora.kluckova@vsb.cz (B.K.); jiri.pokorny@vsb.cz (J.P.); katerina.tomanova@vsb.cz (K.T.)
* Correspondence: simona.slivkova@vsb.cz; Tel.: +420-596-992-814

Abstract: The current safety situation and the conclusions of a number of strategic and conceptual works require a broader integration of the population protection system into the areas of construction management. The approaches adopted by individual countries to this matter differ greatly. In the Czech Republic, the definition of constructions to which it is necessary to apply population protection requirements has not been dealt with sufficiently. The construction technical requirements from the point of view of population protection are also not sufficiently dealt with. This article presents a new draft procedure for designating the requirements for the relevant constructions of population protection in the Czech Republic. In addition, possible external hazards affecting the constructions or their strategic importance functions were assessed. In conclusion, the general, specific, and strategic requirements for constructions are set. The procedure is applied to the conditions of the Czech Republic, but it is also applicable in other countries. The area of public protection is closely related to Industry 4.0. Ensuring the protection of the population, as well as the safety of workers, employers, and production facilities, is one of the basic preconditions for the development of the industry.

Keywords: sustainability of the Industry 4.0; population protection; building safety; building risks

1. Introduction

Population protection, safety, sustainable development, and technological progress are some of the primary aims of the European Union. The principles of the European Union security policy cover, for example, increasing the prosperity of citizens, ensuring sustainable territorial development, support for growth, a safe and healthy environment, and support for the resilience of democratic systems [1]. Global systemic trends and challenges associated with population dynamics, urbanization, disease and pandemics, acceleration of technological changes, and unsustainable economic growth contribute to the fact that dealing with challenges in the area of the environment and attainment of long-term sustainable development is complicated [2].

Territorial safety is closely associated with long-term sustainability. The sustainability strategy is associated with the themes “people and society”, “economic model”, “resilient ecosystem”, “municipalities and regions”, “global development”, and “good management of public affairs” [3,4].

Ensuring territorial safety is one of the main tasks of the state, and public administration plays the primary role in its fulfillment. The safety and sustainability of the territory are ensured by, amongst other things, safety planning, including town planning. Population protection can be included in the designation of requirements in town planning [5].

However, the safety and protection of inhabitants are not only reflected in the area of town planning. The principles of sustainable development are informed by an attempt to ensure that towns are inclusive, safe, resilient, and sustainable [6,7]. The form of the built environment in particular has a significant impact on the ability of society to deal with the problems of climate change or sustainability. The environmental challenges and risks...
associated with climate change impact virtually all towns, and the construction industry plays the main role in this area [8,9].

Certain strategic and conceptual documents demand the broader integration of the population protection system into planning permission proceedings and the use of constructions. Previously, this area tended to focus on the threat of war, but today, one can perceive a shift toward non-military risks. Prevention is an important area [5,10].

The safety of territories and constructions is associated with their vulnerability and readiness [11,12]. Vulnerability is usually understood as a susceptibility to incur harm. It is the property of territories or constructions to react negatively to the impact of an adverse phenomenon. Readiness is the state of preparedness and ability of human, material, and other resources attained as a result of measures adopted in advance, making it possible to ensure the effective and prompt reaction to extraordinary events and crisis situations with the minimization of consequences [13].

The vulnerability of territories and constructions is closely associated with existing risks [14,15]. The general principles of risk management, reducing disaster consequences, and building up resilience constitute the content of strategic and conceptual documents. This consists of, for example, the so-called Yokohama Strategy for a Safer World [16], the Hy-ogo International Strategy for Disaster Reduction [17], and the Sendai Framework for Disaster Risk Reduction [18]. Risk management procedures are developed further by international technical standards, prepared primarily by the International Organization for Standardization [19]. The ISO 31000 standard offers a guide for how to manage various forms of risks in a systematic, transparent, and reliable way and how to harmonize the system of risk management and all decision-making, product, service, and asset processes. The IEC/ISO 31010 standard acts as a supporting standard and provides instruction on the selection and application of techniques for risk assessment [20,21].

The scope of possible risks is extensive and may differ in individual countries or their regions. In Italy, for example, the seismic and hydrogeological aspect is significant. As a result, dealing with earthquakes with the aim of involving all rescue services is one of the civil defense priorities of Italian subjects. Another one of Italy’s priorities is the assessment of critical flood areas for the purposes of civil defense and early warning systems. The installation of a network of rainfall, temperature, and flood sensors can significantly contribute to the creation of an effective warning system [22–24].

South Korea is one of the countries researching how to discover the vulnerability of constructions to high winds. High winds cause critical financial losses to assets. In recent years, the frequency of high winds has increased and, consequently, so has the number of losses caused by high winds. The specified phenomenon has resulted in the need to react to these aspects and create a prediction model based on an “estimate of payouts for insurance events” [25].

Fires are one of the significant risks that the Slovak Republic deals with. However, fire safety is a matter of global interest; the primary aim of which is the protection of human life and health, material assets, and the environment, with a focus on the civil sector. Fire protection is a system of prevention and repression mainly dealt with by the fire brigade in some countries. In other countries, there are institutions that deal with fire hazards differently [26].

Readiness to deal with extraordinary events and crisis situations is closely associated with population protection. The so-called “civil defense structures or structures impacted by the civil defense requirements” can be found in the current approaches of some countries to population protection. In the Czech Republic, structures intended for the protection of the population during extraordinary events, for ensuring rescue work, for the storage of civil defense material, and for protecting and sheltering the staff of important operations are considered to be such structures [27,28].

The Slovak Republic has a similar approach to this matter. The foundation of population protection consists of the conditions for the effective protection of life, health, and property from the consequences of extraordinary events, as well as the tasks andpurview
of bodies of state administration and municipalities, and the rights and duties of natural and legal persons in ensuring civil defense for the population. They build dual-use civil defense facilities which are protective structures and constructions or parts or technological components intended for the fulfilment of civil defense tasks [29,30].

In Germany, a system of “building population protection” has been initiated and is characterized as a set of construction and technical measures capable of offering protection against the consequences of destruction, sabotage, and the effects of weapons of mass destruction of persons, property, and socially important infrastructure. Building population protection is utilized in three areas—population protection, protection of critical infrastructure, and protection of cultural objects [31].

In Switzerland, there is significant cooperation between the confederations, cantons, third parties, and civil defense. This cooperation ensures the effective performance of basic population protection tasks, primarily the protection of inhabitants and their essential needs in the case of disasters and potentially armed conflicts, and it also serves to mitigate their consequences and help deal with them. The designated procedures also contain measures for the protection of cultural objects in the area of construction and equipment of constructions with regard to significant events, i.e., disasters, extraordinary events, and armed conflicts [32].

Ensuring the safety of territories and constructions is associated with the vulnerability and readiness of territories and constructions, and it is thus closely associated with population protection [33]. The European Union focuses considerable attention on readiness to deal with these disruptive events, as evidenced by the civil defense mechanism that has been created [34,35].

However, the safety of society is not associated with the protection of territory and constructions alone. Manufacturing and industry also contribute significantly to a safe and sustainable society. New production technologies have always constituted an advantage for every society because they ensure faster and more flexible production [36].

The digital transformation of industry is a crucial part of the broader transformation of the economy, which includes automation, materials sciences, and new production procedures, and is referred to as Industry 4.0. Many countries have been caught up in the current trend of the digitization and automation of production within Industry 4.0. However, the approach to this development and its intensity varies from country to country. Initiatives take different forms, with each country developing its own vision of Industry 4.0 and its future [37].

For example, the Belgian Made Different initiative [38] aims to make the manufacturing industry competitive by digitizing production processes, thus transforming manufacturing companies into the so-called factories of the future. The aim of the Luxembourg national initiative Digital for Industry [39] is to raise awareness of the introduction of Industry 4.0 in small, medium, and large enterprises. The Swiss initiative Industrie 2025 [40] sets out the main objectives, which are the analysis of the risks arising from networked industrial machinery and equipment, the definition of business activity from the perspective of safety in Industry 4.0, and the analysis of a suitable working environment. The Czech Republic’s approach to this trend is further elaborated in Section 2.4.

The advantages of implementing the principles of Industry 4.0 already become apparent in the general definitions of Industry 4.0, specifically in the individual initiatives. However, it is still necessary to perceive the possible disadvantages of this system. One such disadvantage is, for example, the lack of a uniform definition, which represents a serious limitation for building theory and comparability of research. However, the potential impact of new developments in the manufacturing and industrial process on safety, sustainability, and the environment, among other things, is still unknown. Alongside the positive impact on worker health, we also see new risks in the area of process safety and occupational health protection [41–44].

As in the normal functioning of society, the issue of safety must also be viewed comprehensively in Industry 4.0. This comprehensive perception has many components.
One of the basic components is risk perception. A risk register may be an appropriate tool for risk management and safety [45,46]. It is also appropriate to pay increased attention to the actual implementation of Industry 4.0 and all technologies in the current manufacturing society [47]. The priority of the European Union and its Member States is therefore to create the conditions for the implementation of the Industry 4.0 strategy. This effort is closely connected with ensuring the safety of territory, buildings, and technologies.

The paper’s goal is to present a new procedure for determining the construction technical requirements for buildings, to ensure the protection of the population. The aim of these requirements is to increase the safety situation of ordinary as well as industrial buildings, primarily from the point of view of the protection of buildings from external dangers and to facilitate the functioning of the integrated rescue system and crisis units. The proposed procedure covers all the above-mentioned areas. This process has been developed as part of the safety research of the Czech Republic.

2. Materials and Methods

Ensuring population protection and also including the safety of employees, employers, and production operations, is one of the basic preconditions for the safe and sustainable development of society and industry.

2.1. The Methodology Used to Create the Procedure for Determining the Construction Technical Requirements for Population Protection

The authors used several basic as well as specific scientific methods in creating the paper [48,49]. In the introductory part of the survey, research on existing procedures used to determine the construction technical requirements for buildings in terms of protection of the population in the Czech Republic and in selected foreign countries was processed. Attention was focused mainly on countries in which the system of population protection is similar to the system used in the Czech Republic. At the same time, research was conducted on the classification of structures from various perspectives, in particular from the perspective of regulations related to safety, critical infrastructure, design and execution of structures, and recording of structures in cadastral maps.

Based on the description, a basic overview of the classification of buildings was compiled, which was used in the next steps of the solution. Information related to the identified requirements for constructions from the perspective of population protection was analyzed. Using the principles of deduction, the initial algorithm of the procedure for determining the construction technical requirements for buildings from the perspective of population protection was compiled.

Special attention was paid to the assessment of external hazards to which structures may be exposed. The bases for the evaluation were the threat analyses prepared for the Czech Republic and its constituent areas. Threats with unacceptable risk and conditionally acceptable risk were assessed. Multi-criteria decision analysis was applied to assess the threats, applying the following four criteria:

- Assessment of the impacts of typified hazards within the Threat Analysis for the Czech Republic,
- Evaluation of the possibility of introducing preventive measures in terms of construction and technical properties of the building,
- Evaluation of the possibility of preventive measures from the perspective of the competence of the fire brigade,
- Assessment of the insufficient solution of the given danger in the relevant regulations.

The criteria were chosen with regard to the current state of resolution of the issue in the Czech Republic. The result was threats that were positively assessed by all criteria. Using the synthesis of the acquired knowledge, a new, generally applicable procedure for determining the requirements for structures from the perspective of population protection was proposed. The essence of the procedure is the definition of structures of interest for the protection of the population and their subsequent classification into vulnerable,
strategic, and other structures of interest. Subsequently, the requirements for the protection of the population in the context of building permit proceedings are determined for each category of structures of interest.

Finally, possibilities in general for the use of the proposed procedure were formulated using induction. The whole process of procedure development was continuously accompanied by brainstorming sessions, and in some cases, also structured or semi-structured interviews.

2.2. Definition of Basic Terms

The term “population protection” in the Czech Republic means the fulfilment of the civil protection tasks, especially the warning, evacuation, shelter, emergency survival of the population, and other measures to ensure the protection of life, health, and property. From the practical aspect, it consists of a set of activities and tasks of the responsible bodies of state administration, legal and trading persons, and also citizens leading to ensuring the protection of life, health, property, and the environment [10,27].

According to Additional Protocol I of the Geneva Conventions, “civil protection” is defined as the performance of tasks intended to protect exclusively the civilian population against the hazards and to help it to recover from the effects of wars and disasters [50].

The services of the integrated rescue system (the fire brigade, police, and ambulance service) participate in dealing with extraordinary events and crisis situations. The joint approach of the specified services is described as the “integrated rescue system” and is developed on an ongoing basis [27,51].

The “population protection requirements” are determined in the newly designed procedure. These are requirements of a technical and organizational nature asserted for relevant constructions with the purpose of population protection.

“Construction” means all building works created through building or assembly technology, regardless of their construction-technical version, the building products, materials and structures used, the purpose of use, and duration [52].

The term “groups of constructions” covers various approaches to the division of constructions, i.e., groups of constructions according to their typology or classification (such as transport constructions, constructions for trade, administrative constructions, etc.) [53].

“Relevant constructions of population protection” are buildings to which the requirements of population protection are applied. These are buildings that are of interest from the point of view of population protection. These can be existing structures or also structures that are still in project management stages. Relevant constructions are sub-divided into vulnerable constructions, strategic constructions, and other relevant constructions. “Vulnerable constructions” are constructions where there is a large concentration of people, where there are persons with reduced mobility, where there are persons up to the age of 15, or where there are persons unfamiliar with the environment in construction with possibilities for sleeping. The geometry of the constructions is also taken into account. Constructions significant for the running of the region (local government tier) the disruption of which would have a serious impact on the safety or functioning of the given territory is designated as “strategic constructions”. “Other relevant constructions” are constructions that can be used for the needs of population protection, in particular for the location of end elements for monitoring and warning, for the activity of crisis teams, for emergency survival, and for priority care [54].

The essence of “population protection in planning proceedings” is the definition of relevant constructions in the context of planning proceedings, the definition of the population protection requirements for these constructions, and the procedure for their application [54].
2.3. Planning Proceedings in the Czech Republic in Relation to Population Protection

The legislative basis in the area of planning proceedings in the Czech Republic is the Building Act [52], which designates the conditions for granting permission for constructions, changes and alterations to them, the performance of earthmoving, the use and removal of constructions, and the performance of other acts.

According to the current legislation in the Czech Republic, population protection requirements can be asserted in planning proceedings by the regional fire brigade, which is the interested authority in planning proceedings and in joint zoning and planning proceedings from the aspect of population protection. The fire brigade supervises adherence to the requirements of legal regulations in the area of population protection.

The current conception of this matter in the Czech Republic has not been resolved sufficiently and comprehensively. The determination of constructions for population protection and the definition of the requirements for it tends to be dealt with intuitively.

2.4. Industry 4.0 under the Conditions of the Czech Republic

For several years now, many advanced countries have been dealing with the start of the fourth industrial revolution, which will fundamentally change the nature of the industry, energy generation and distribution, trade, logistics, and other components of the economy and society as a whole. The Czech Republic cannot remain outside these events. The main concept is to cover the impulses which bring to national industry this entirely new philosophy of systemic use, integration, and linkage of different technology when considering their permanent and very rapid development and to prepare conditions for the industrial manufacturing and non-manufacturing sphere to implement the new industrial revolution. The long-term aim of this initiative is to maintain and strengthen the competitiveness of the Czech Republic at a time when this philosophy is taking hold on a large scale throughout the world [55].

The basic document covering this matter in the Czech Republic is the Initiative Industry 4.0 [56]. Its aim is to indicate possible directions for development and outline measures that could not only support the economy and industrial base of the Czech Republic but also help prepare society to absorb this technological change. The initiative contains basic information about the need for urgent changes caused by the start of the 4th industrial revolution, and it outlines the measures in support of investment, applied research, and standardization. It also covers questions associated with cybersecurity, logistics, and legislation.

Another goal of the Industry 4.0 initiative is to mobilize the business community and all the aforementioned interested parties to become actively involved in its implementation and realization under the conditions of the Czech Republic [56].

2.5. Designation of Population Protection Requirements for Constructions

The procedure for determining the requirements for the protection of the population for buildings of interest is based on the basic aspects:

- category of construction,
- vulnerability of construction,
- external hazard of construction,
- strategic significance of construction.

The categories of constructions within the area of population protection are, for example, administrative constructions, constructions for trade, constructions for healthcare, schools, and universities, etc. [57]. The constructions are then compared with other criteria:

- if the constructions comply with the vulnerability criteria and their limit values, the general requirements of population protection are applied to them,
- if the constructions are exposed to external hazards, specific requirements are applied to them,
• if they are constructions of a strategic significance, requirements for ensuring greater resilience (i.e., strategic requirements) are also applied to them. The procedure is illustrated in principle in Figure 1.

![Figure 1. Depiction in principle of procedure for determining the requirements for relevant constructions of population protection.](https://via.placeholder.com/150)

### 2.6. Limiting Conditions of the Solution

The presented procedure for determining the requirements for relevant constructions of population protection was drawn up on the basis of the following limiting conditions:

- population protection requirements not coming within the purview of the Fire Brigade of the Czech Republic were not dealt with,
- the construction technical requirements for population protection that would significantly impact the area of the ownership rights of natural persons (partial restriction of ownership right is permissible but only in the absolutely essential cases) were not covered,
- construction-technical requirements of population protection were not designated for those types of constructions for which it is not possible to designate limit criteria or concrete requirements.

### 3. Process and Results

This part of the article describes the procedure for designating the requirements for relevant constructions of population protection in the Czech Republic, i.e., the principle by which the relevant constructions were designated, the hazard identified, and the population protection requirements were designated.

There is a comprehensive description of the procedure so that the other activities leading to the fulfilment of this procedure are also presented. The procedure can be adopted to the conditions of other countries by this presentation. The entire procedure is depicted in Figure 2.

The process for designating the requirements of population protection for constructions can be divided into four steps, marked A–D in Figure 2. The first step focuses on the use of existing groups of constructions (step A). These groups are selected according to designated criteria. The output from this step is a list of results of relevant groups of constructions, see Section 3.1.
Figure 2. More detailed illustration of the procedure for designating the requirements of population protection for relevant constructions.

The next step takes into account and evaluates possible hazards that can have a negative impact on the groups of constructions (step B). The result of this step is a list of hazards acting on the relevant group of constructions, see Section 3.2.

The next step (step C) focuses in more detail on the selection of specific relevant constructions from the population protection aspect. This selection is made using the designated parameters and limits criteria. As a result of this step, the relevant constructions are classified as vulnerable constructions, strategic constructions, and other relevant constructions, see Section 3.3.
General construction-technical requirements are designated for vulnerable constructions. In addition, construction-technical requirements are designated for constructions threatened by external hazards. Strategic construction-technical requirements are asserted for constructions classified as strategic (step D), see Section 3.4.

The details of the individual steps and concrete limit criteria are described in the following sections.

3.1. Designation of Relevant Groups of Constructions (Step A)

This part of the article describes in detail the designation of relevant constructions out of the total group of identified constructions. The total group was drawn up on the basis of an analysis of the approaches to the classification of constructions using different sources [52–54, 58–60]. The resultant primary selection of the group of identified constructions was based on two characteristics, which are the vulnerability and strategic nature of constructions.

The character of the use of constructions may increase the overall vulnerability of the given construction. For this reason, it is necessary to identify these constructions and focus attention on them when designating measures. In this step, only the primary selection is performed, which is carried out using the following criteria for assessment of possible vulnerability:

- assumption of the presence of a large number of people,
- assumption of the presence of persons with reduced mobility,
- assumption of the presence of persons up to the age of 15,
- assumption of the presence of persons unfamiliar with the environment in constructions with possibilities for sleeping.

A group of constructions that meets at least one of the above criteria is given as a relevant group of constructions. Based on the performed primary selection of constructions in the Czech Republic, there was a definition of vulnerable constructions which are represented by 10 groups of vulnerable constructions:

- administrative constructions,
- constructions for trade,
- constructions for healthcare,
- constructions for social, cultural and religious purposes,
- schools, universities, and constructions for research,
- hotels and accommodation facilities,
- constructions for transport,
- constructions for industry,
- social care constructions,
- constructions for sport and recreation.

From the aspect of strategic significance, those constructions which are essential for the running of the given territory, primarily the territory of the region (local government tier), are selected. A disruption to the functionality of these constructions could have an impact on the safety of the population or significantly restrict the usual life of inhabitants in the territory.

As part of the primary selection, three groups of strategic constructions significant for the running of the region (territory) were defined:

- constructions for healthcare,
- constructions for transport,
- constructions of emergency services.

In addition to these constructions, it is necessary to take into account other constructions serving specific requirements of population protection. In the Czech Republic, these are specifically civil defense constructions and constructions impacted by civil defense requirements. These constructions are specified in more detail in the following steps.
3.2. Hazard Assessment for Relevant Groups of Constructions (Step B)

This section specifies in more detail the assessment of external hazards in relation to relevant constructions. The basis for the step is the identification of hazards that could have an impact on the above-selected groups of relevant constructions. The basic input for determining the resultant hazards for the Czech Republic was the already-drawn-up analyses. These were primarily the Analysis of Threats for the Czech Republic and associated Analysis of Threats to Regions [61,62]. In total, 72 types of hazards divided into three categories were assessed in these original documents. These were categories with an acceptable hazard, conditionally acceptable hazard, and unacceptable hazard.

Those hazards which were assessed in the analysis as a type of hazard with unacceptable risk and a type of hazard with conditionally acceptable risk were used to designate the hazards for the relevant group of constructions. It was not necessary to make a further evaluation of the acceptable risks according to risk assessment principles [20,21].

In total, 22 hazards are included in the category with unacceptable hazard, including floods, high winds, radiation accident, leak of a hazardous chemical substance from the stationary facility, epidemic, largescale disruption to food supplies, migration, etc. The category with conditionally acceptable hazard consists of 26 hazards, including tornado, snow disaster, frost, unstable slope, fires, serious traffic accident, etc.

For the application of multi-criteria decision analysis, the criteria were indicated in the following way:

- assessment of impacts of type hazards as part of Threat Analysis for Czech Republic (criterion E),
- assessment of possibilities for the introduction of preventative measures from the aspect of construction-technical properties of construction (criterion F),
- assessment of possibilities for preventative measures from the aspect of competence of the fire brigade (criterion G),
- assessment of insufficient resolution of given hazard in relevant regulations (criterion H).

Table 1 shows the risk evaluation according to the aforementioned criteria for hazard with unacceptable risk based on a Threat Analysis. A hazard with a conditionally acceptable risk was evaluated in the same way.

Table 1. Assessment of hazard with unacceptable risk.

| Designation of Hazard | Hazard with Unacceptable Risk                                                                 | Criterion |
|-----------------------|---------------------------------------------------------------------------------------------|-----------|
|                       |                                                                                             | E   | F   | G   | H   |
| N-01                  | natural flood                                                                               | yes | yes | yes | yes |
| N-02                  | flash flood                                                                                 | yes | yes | yes | yes |
| N-03                  | extreme wind                                                                               | yes | no  | no  | yes |
| N-04                  | extreme long-term drought                                                                   | yes | no  | no  | yes |
| N-05                  | extremely high temperature                                                                  | yes | no  | no  | yes |
| A-01                  | special flood                                                                              | yes | yes | yes | yes |
| A-02                  | leak of hazardous chemical substance from stationary facility                               | yes | yes | yes | yes |
| A-03                  | radiation accident                                                                          | yes | yes | yes | yes |
| A-04                  | large-scale power cut                                                                       | yes | yes | yes | yes |
| A-05                  | large-scale breakdown in law and order                                                       | yes | no  | no  | yes |
| A-06                  | large-scale disruption to drinking water supplies                                           | yes | yes | yes | yes |
| A-07                  | disruption to functionality of important electronic communications                           | yes | no  | no  | yes |
| A-08                  | large-scale migration waves                                                                  | yes | no  | no  | yes |
| A-09                  | large-scale disruption to gas supplies                                                      | yes | no  | no  | yes |
| A-10                  | disruption to information security of critical information communications                  | yes | no  | no  | yes |
| A-11                  | large-scale disruption to food supplies                                                     | yes | no  | no  | yes |
| A-12                  | large-scale disruption to financial and foreign exchange system                              | yes | no  | no  | yes |

Note: N = natural hazards, A = anthropogenic hazards.
The number of attained criteria for conditionally acceptable hazards and unacceptable hazards is shown in Figure 3.

![Figure 3. Number of attained criteria of individual hazards.](image)

Hazards that meet all four basic criteria are considered resultant. For the Czech Republic they are:
- N-01 natural flood,
- N-02 flash flood,
- A-01 special flood,
- A-02 leak of hazardous chemical substance from stationary facility,
- A-03 radiation accident,
- A-04 large-scale power cut,
- A-06 large-scale disruption to drinking water supplies.

### 3.3. Parameters for Selection of Relevant Constructions of Population Protection (Step C)

Another point of the procedure is the selection of concrete relevant constructions using the configured criteria or their parameters.
3.3.1. Vulnerable Constructions

In the Czech Republic, vulnerable constructions are constructions where there is a large concentration of people, where there are persons with reduced mobility, where there are persons up to the age of 15, or where there are persons unfamiliar with the environment in constructions with possibilities for sleeping.

Concrete parameters of the criteria expressing the numbers of persons in the given construction or specification of the construction were assigned to these vulnerability criteria. The values for the concrete parameters of criteria were gained through an analysis of various approaches, such as [57,63–65]. These criteria are displayed in Table 2.

| Vulnerability Criteria | Parameters of Criteria |
|------------------------|------------------------|
| assumption of presence of large number of people | >1000 people |
| assumption of presence of persons with reduced mobility | >100 people |
| assumption of presence of persons up to the age of 15 | >200 people |
| assumption of presence of persons unfamiliar with the environment in constructions with possibilities for sleeping | >100 people |
| geometry of construction | taller than 22.5 m, taller than 45 m, more than 2 above ground stories, more than 1 below ground story, more than 2 below ground stories |

Note: Another vulnerability criterion is also the influence of the construction’s geometry, i.e., height of construction or number of above ground or below ground stories. The geometry of the construction has a fundamental significance from the aspect of evacuation and rescue of persons.

Table 3 shows the resultant overview of vulnerable constructions designated by a combination of the criteria of vulnerability and their parameters.

| Groups of Constructions | Parameters of Vulnerability Criteria |
|-------------------------|-------------------------------------|
| administrative constructions | constructions taller than 45 m or having more than 2 usable underground stories or constructions with presence of more than 1000 persons |
| constructions for trade | constructions with presence of more than 1000 persons |
| constructions for healthcare | constructions with more than two usable above ground stories or more than one usable underground story in which there are more than 100 persons requiring support during evacuation |
| constructions for social, cultural and religious purposes | constructions in which there may be more than 1000 persons |
| schools and universities | nursery school constructions in which there are more than 100 persons; primary school and secondary school constructions in which there are more than 500 persons; university constructions in which there are more than 1000 persons |
| constructions for accommodation | constructions taller than 22.5 m or having more than 2 usable underground stories or constructions intended for the accommodation of more than 100 persons |
| constructions for transport | constructions with presence of 1000 or more persons |
| social care constructions | constructions with more than two usable above ground stories or more than one usable underground story in which there are more than 100 persons requiring support during evacuation |
| constructions for sport and recreation | constructions in which there may be more than 1000 persons |
3.3.2. Strategic Constructions

Constructions essential for the running of the given territory are considered to be strategic constructions. Their disruption causes a threat to human life and health, or it causes damage to property or has a fundamental impact on the running of society. Groups of strategic constructions were designated on the basis of the specified criteria. Constructions meeting at least one of the specified criteria (see Table 4) are considered strategic constructions.

Table 4. Strategic constructions and their criteria parameters.

| Strategic Constructions                      | Parameters of Criteria                                                                 |
|---------------------------------------------|----------------------------------------------------------------------------------------|
| constructions for healthcare                | constructions of inpatient care providers in which acute, convalescent or long-term care is provided |
| constructions for transport                 | central control site, national transport information center, or air traffic control construction |
| constructions of emergency services         | operations centers and stations of basic components of integrated rescue system          |

3.3.3. Other Relevant Constructions

The third category of constructions is the other relevant constructions from the aspect of population protection, which are constructions supporting the resolution of extraordinary events and crisis situations. These are:

- constructions suitable for locating monitoring end elements,
- constructions suitable for locating electronic warning end elements,
- constructions suitable for activities of crisis teams,
- constructions suitable for emergency survival,
- constructions intended for preferential care.

3.4. Designation of Population Protection Requirements for Relevant Constructions (Step D)

Based on the preceding steps it is possible to draw up requirements for relevant constructions of population protection. For the Czech Republic population protection requirements have been divided up into the following categories:

- general construction-technical requirements (designated for relevant constructions which comply with the vulnerability criteria and their limit values),
- specific construction-technical requirements (designated for relevant constructions exposed to external hazards),
- strategic construction-technical requirements (designated for relevant constructions of strategic significance).

General construction-technical requirements focus on the area of population protection and the integrated rescue system of the Czech Republic and are given in Table 5.

Table 5. General construction-technical requirements.

| Area                          | General Construction-Technical Requirements                                                                 |
|-------------------------------|-------------------------------------------------------------------------------------------------------------|
| population protection         | requirements for warning within constructions                                                               |
|                               | requirements for ensuring deliveries of electricity                                                           |
| integrated rescue system of the Czech Republic | requirements for access roads—their parameters, load limit, number of lanes, etc.                      |
|                               | requirements for ensuring source of fire water—their location and capacity, pumping station                  |
The specific construction-technical requirements focus on protection from hazardous chemical substances, protection from floods and protection from radiation accidents, and they are given in Table 6.

Table 6. Specific construction-technical requirements.

| Area                          | Specific Construction-Technical Requirements                                                                 |
|-------------------------------|---------------------------------------------------------------------------------------------------------------|
| protection from hazardous chemical substances | installation of end elements of dangerous substance monitoring and connection of those elements to emergency audio system in construction |
|                               | possibility to halt operational air-conditioning equipment, etc.                                             |
| flood protection               | requirements for connection of audio system in the construction to public warning system                       |
| protection from radiation accidents | installation of end elements of radiation monitoring and connection of those elements to emergency audio system in construction |
|                               | possibility to halt operational air-conditioning equipment, etc.                                             |

The last category of population protection requirements is strategic construction-technical requirements, i.e., requirements focusing on the area of strategic constructions and other relevant constructions. Examples of these requirements are shown in Table 7.

Table 7. Strategic construction-technical requirements.

| Area                          | Strategic Construction-Technical Requirements                                                                 |
|-------------------------------|---------------------------------------------------------------------------------------------------------------|
| detection and warning systems | allow the installation of equipment and its connection to the system for warning inhabitants, allow its maintenance |
|                               | ensure backup electricity source                                                                               |
| activity of crisis teams       | install backup electricity source                                                                               |
| strategic constructions        | install backup electricity source and establish connection point                                              |
|                               | create supplies of drinking and non-potable water                                                             |

4. Discussion

The development and sustainability of the territory are closely associated with its safety. In order to ensure the safety of a territory, it is necessary to carry out an ongoing evaluation of the hazards present in the given territory and designate essential preventative measures.

The safety of constructions located on a given territory is also associated with the safety of that territory. Some of the constructions constitute certain hazards due to the very nature of the construction or its operation. As in the case of territory, it is also essential to assess the external hazards that the constructions may be exposed to and designate preventative measures.

The development of territory and constructions is closely associated with the development of new technologies. The most powerful impetus of recent years in relation to the development of technologies is Industry 4.0, which is associated with the development and implementation of digital transformation and automation in manufacturing. Historically, the development of manufacturing is accompanied not only by the development of safety measures but also by the inception of new risks. The risks, which are mainly of an anthropogenic nature, intersect with naturogenic risks.
To achieve comprehensive safety of the territory, it is necessary to focus on all elements of the territory, i.e., on both the population and structures in the territory. Industrial buildings are then also considered to be structures in the territory, often developed in the meaning underdevelopment of Industry 4.0. The safety of the territory and all structures can be significantly positively influenced by the appropriate application of the requirements for the protection of the population. The appropriate application of population protection measures should therefore affect both conventional buildings and Industry 4.0 buildings.

At present, there is only a very limited application of the requirements for population protection to constructions in the Czech Republic. The main reason is the ambiguity of the specified requirements; neither is it clear to which constructions they should apply. The specified shortcomings were the reason why the research intended to rectify this state was initiated.

The result of the solution is a new approach specifying so-called relevant constructions from the aspect of population protection and designating the conditions for them. These constructions include vulnerable, strategic, and other relevant constructions where population protection requirements are to be applied. The constructions were designated on the basis of the criteria and their parameters.

The described classification of constructions primarily consists of two basic levels reflected in the risk assessment, i.e., vulnerability and readiness. This is a general classification that should not be conflicting in most countries [66,67].

For the specified categories, there is a designation of general requirements for constructions located on the territory without external hazards, specific requirements for constructions on the territory with external hazard, and strategic requirements for ensuring the operability of selected constructions or facilities for dealing with extraordinary events and crisis situations.

To a certain extent, the designated requirements of population protection for constructions were influenced by process rules associated with the permitting and implementation of constructions, legal regulations, and technical standards in the Czech Republic. One can assume that the character and scope of the requirements differ to a certain extent in other countries [68].

Special attention was paid to the selection of the external hazards which are to be taken into account when the population protection requirements are designated. The basis was the Analysis of Threats for the Czech Republic and Analysis of Threats to Regions. Based on the selected criteria, natural floods, flash floods, and special floods were designated, as was a leak of a hazardous chemical substance from the stationary facility, radiation accident, large-scale power cut, and large-scale disruption to drinking water supplies. In spite of the fact that constructions can be threatened by several hazards, others were not taken into account for designating the requirements for constructions under the conditions of the Czech Republic. The reason was primarily the competence of the guarantor for population protection, which is the Ministry of the Interior of the Czech Republic, and the possibility to implement the designated measures. The selected hazards would probably not be wholly suitable for other countries, where the hazards present in their territories must be assessed. However, the focus of many of the papers suggests that the list of selected hazards is adequate and also coincides with the interests of other countries, e.g., [23,24,26,69,70].

One of the current problems in the world is the COVID-19 pandemic. All over the world, the COVID-19 pandemic has had a serious impact on human life, the economy, the environment, energy, and transport [71]. Pandemics are one of the threats identified in the Threat Analysis for the Czech Republic. Pandemics can trigger numerous measures in terms of population protection, such as increased demands on the crisis management system or increased demands on the scope of medical care. In terms of the possibility of endangering structures as such or their function, pandemics cannot be systematically addressed in construction management. For this reason, the COVID-19 pandemic is not taken into consideration in the newly proposed procedure. From a different perspective on this hazard and the current situation in the world, it is clear that certain structures, with
minor modifications, can be used to deal with pandemics or other emergency situations. Examples include workplaces for crisis teams or medical care facilities.

One new feature of the created procedure is the creation of an integrated system for designation of the population protection requirements for constructions including suitable terminological definitions, classification of relevant constructions, the reflecting of external hazards, and the definition of concrete requirements. In spite of the fact that the specified procedure to a certain extent reflects the specific conditions of the Czech Republic, it can be applied in principle in other countries.

The population protection requirements, which are the final result of the application of the new procedure, can also be taken into account in the constructions as part of the developed system of building information modelling. The Ministry of Industry and Trade acts as the guarantor for the implementation of the specified system in the structures in the Czech Republic. Implementation is carried out in compliance with the prepared concept [72], and its practical application is assumed for 2022 when the use of the system building information modelling will be required for some types of constructions. The introduction of an information system for constructions is called the digital transformation of construction or also Building 4.0, which is directly linked to Industry 4.0.

5. Conclusions

It is clear from the strategic and conceptual materials, as well as from the current unstable safety situation in the world, that it is necessary to continuously implement preparatory measures to deal with emergencies and crisis situations. The preparation for dealing with these events goes hand in hand with the implementation of the construction and technical requirements for buildings when it comes to protection of the population. The requirements should focus on structures of interest, in terms of protection of the population, which are vulnerable, strategic, and other structures of interest. All types of buildings have their specific importance in terms of the protection of the population.

The scope of the structures of interest and construction technical requirements to be implemented in terms of protection of the population vary from country to country. The current situation in the Czech Republic is highly problematic in this respect. The types of buildings of interest in terms of the protection of the population are not precisely defined and the application of the construction technical requirements is unclear. This unsatisfactory situation has long been considered unsustainable, and new solutions have had to be sought.

The article presents a new procedure for the classification of structures from the perspective of the protection of the population and the subsequent determination of construction technical requirements for these structures. The procedure includes hazards arising both from the actual operation of the structures as well as external hazards. The assessment of external hazards was based on the analyses of threats in the Czech Republic. The presented procedure was developed within the framework of the Safety Research of the Czech Republic. The result of the research is a methodology certified by the Ministry of the Interior of the Czech Republic, which is currently the basis for the preparation of a legal regulation that sets out the construction technical requirements for buildings in terms of protection of the population.

The safe operation of buildings is closely linked to the context of the fourth industrial revolution, Industry 4.0. Ensuring long-term sustainability, which is closely linked to safety, is a fundamental requisite for the successful implementation of this breakthrough plan. The new procedure for determining the technical and construction requirements for structures with respect to the protection of the public is one of the forms that can create the conditions for the successful development of the Industry 4.0 concept.

Subsequent application of the requirements for the protection of the population for new buildings is a non-problematic matter. The opposite is true for existing buildings, where it would be necessary to apply the structural engineering requirements with some caution. For existing buildings, it is expected that the above requirements will be imple-
mented when major building alterations are carried out. The application of the procedure leads to an increase in their safe operation. It is an important step in terms of preparing buildings for dealing with emergencies. The procedure may find an application not only in the Czech Republic but also abroad.

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