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Tornado Strike in Mikulčice and Options for Dealing with its Consequences

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Abstract

In 2021, the South Moravia region of the Czech Republic was dealing with the aftermath of tornado. This extraordinary event, which is not very frequent in the Czech Republic, was associated with the implementation of a considerable amount of efforts aimed at rescue, liquidation and subsequent recovery work. Using this emergency as an example, it can be stated that it is evident that climatic and meteorological conditions are changing significantly in connection with global climate change and are also affecting the territory of the Czech Republic. It is therefore very realistic to expect that the occurrence of emergencies associated with surprising and often difficult to predict emergencies will become more and more common, and it is therefore necessary to constantly prepare, not only at the level of public authorities, but also at the level of school facilities. The main body of the article focuses on the specification of proposals and measures that could be taken in any municipality affected by such or similar emergencies. Not only the proposals related to the implementation of recovery (technical) works, but also to the protection of the population, especially in the field of its education, have been elaborated in detail. Increasing the level of education and preparedness of the population can make a significant contribution to better managing the impact of emergencies of the same or similar nature.

KEY WORDS: *Tornado, emergency, protective measures, meteorological phenomenon, Mikulčice, prevention, school, Fujita scale, population*

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1. Introduction

The occurrence of strong and destructive tornadoes is not a frequent natural phenomenon in the Czech Republic (CR) [1,2]. Although there are units of tornadoes formed annually in the Czech Republic, these are tornadoes of a weaker nature, which are practically not reported. Despite this, a tornado of a very strong nature occurred in South Moravia in 2021. Specifically in the village of Mikulčice, which is the primary focus of the communication, it devastated almost half the village. At the outset, we would like to add that although it might seem that the declared relatively rare occurrence of this extraordinary event (EE) may not be of much interest and that it does not need to be systematically addressed, another devastating tornado also occurred in the Svitavy region in 2023. This tornado also caused considerable property damage, but in comparison to the events in South Moravia it was disproportionately smaller.

Although this is a natural phenomenon that occurs relatively rarely in the CR, it is necessary to actively prepare for this type of EE. Although this is undoubtedly a sequence of very tragic events, the subsequent reconstruction of the village should be seen not as a mere rebuilding and restoration, but as an opportunity to prepare effectively in case a similar EE occurs again [3].

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2. Characteristics of the Tornado

2.1. General characteristics of the tornado

Very briefly, it can be stated that a tornado is a dangerous convective phenomenon that can cause tremendous local or regional damage. Although Zakharov [4] claims that tornadoes are one of the basic meteorological phenomena, this is not entirely true for the CR. In general, a tornado can be characterized as an unlikely EE, but one that is characterized by severe consequences [5]. Rauhala [6] states that a tornado is a vortex located between clouds and land or water where the connection between the cloud and the surface is visible, or the vortex is strong enough to cause damage equivalent to at least F0 on the Fujita scale.

Tornadoes usually occur where a cold front meets a warm front. They are associated with strong winds, rain and hail. Wind speeds accompanying a tornado can range from 64 km/h to 512 km/h. The tornado itself is then a rotating column of air that extends from the storm cloud to the Earth's surface. Although tornadoes are described as a short-lived phenomenon that affects only a limited area, they have the potential to cause significant material damage and severe EE. Tornadoes can also cause a significant number of injuries and deaths. In addition to the above, they also cause secondary disasters such as fires and floods.

2.2. Tornado strength

A standard method for direct measurement of wind speed during tornado occurrence is currently lacking, which is a major obstacle in assessing EE intensity. Damage done is usually the only information available. Several scales and methods have been developed for the purpose of comparing events based on damage done. The most well-known scale is the Fujita scale (F-scale). Other wind speed scales include the TORRO scale (T-scale), and a more recent expanded version of the Fujita scale [7]. All scales and the relationships between them are shown in Figure 1.

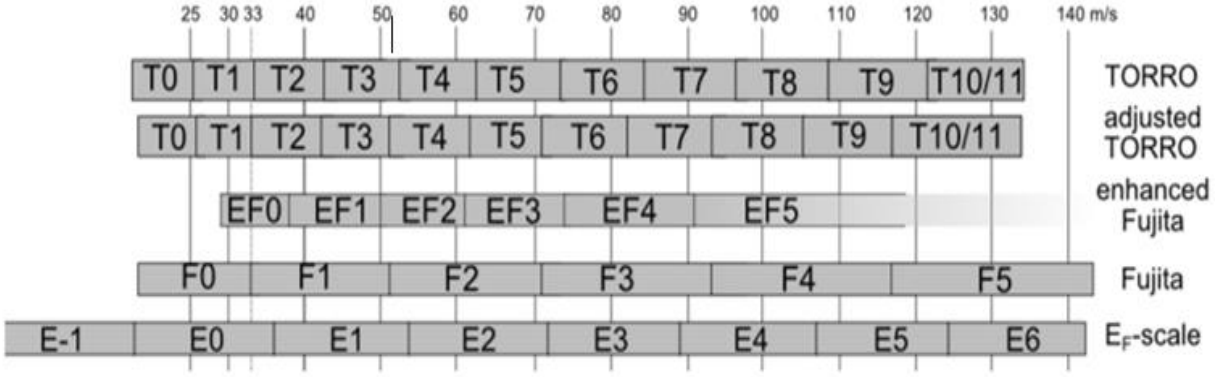

Fig. 1. Wind speed scale for assessing tornado damage (source: [8])

The Fujita Scale and TORRO Scale describe the effects of wind on various objects using numbers and based on the damage, determine the ranges of wind speeds that are believed to be responsible for the respective damage. On both the Fujita and TORRO scales, the higher the number, the more severe the effects and the higher the wind speed. In the United States, the Fujita and TORRO scales were in use until 2007, and in Europe and other regions these scales are still in use today. Clearly, tornado strength cannot be measured based on damage, given that the extent of damage is closely related to the tornado's trajectory and the presence or absence of objects that may be damaged. Thus, the strength of some tornadoes may have been underestimated because there were not enough objects in their path that could be damaged.

3. Tornadoes in the Czech Republic

Brázdil et al [9] state that 161 tornadoes occurred or probably occurred in the CR between 1119-1999. Brázdil [5] reports that 307 tornadoes were documented in the CR from 1119 to 2010. Brázdil [9] further states that from 1119 to 2019, 108 occurrences or probable occurrences of severe (F2 or F3) tornadoes have been documented in the CR. Figure 2 shows the occurrence of tornadoes and probable tornadoes in the CR between 1501-2010.

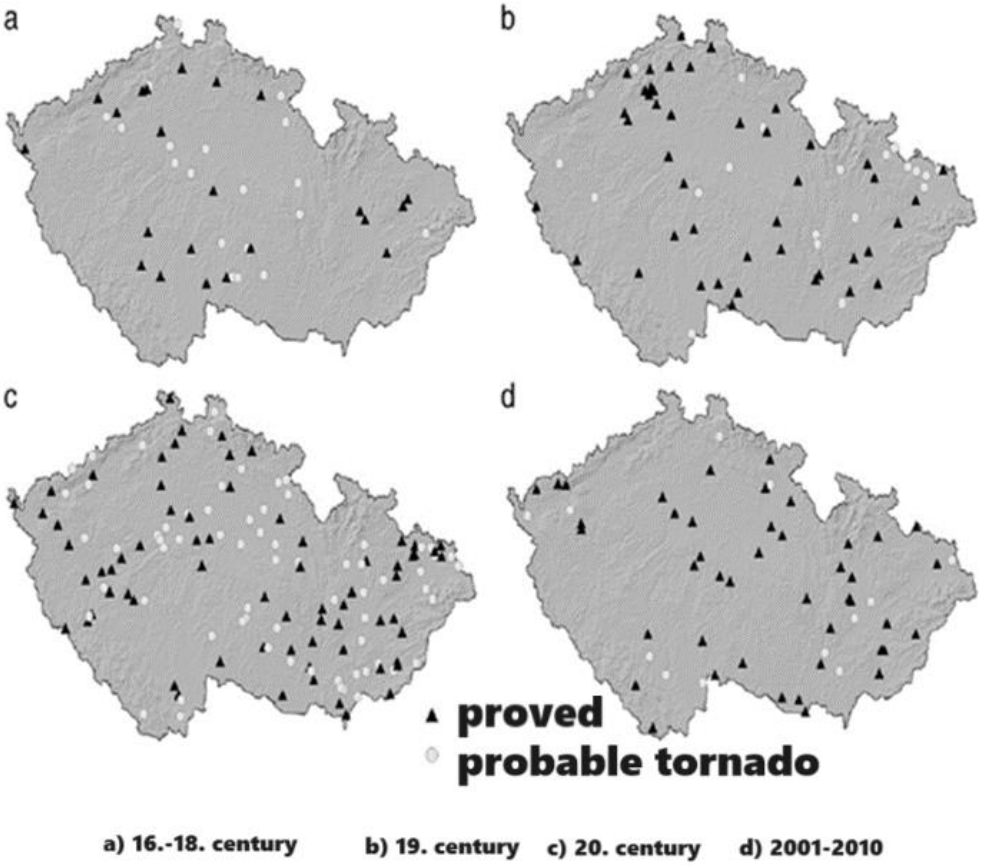

Fig. 2. Incidence of tornadoes in the Czech Republic between 1501-2010 (adapted from [9]

The first recorded case of a tornado dates to 1119, when a relatively strong tornado destroyed Vyšehrad Castle in Prague. Based on historical records, this tornado was given a force of F3. Only 3 other cases were recorded before 1500. Over the next 3 centuries, 11 to 16 tornadoes per century were documented [5]. Setvák [10] points out two significant gaps in the historical record of tornadoes in the CR. The first gap begins in the 14th century and ends in the second half of the 16th century. The second gap then dates from the beginning of the 17th century to the end of the 18th century. The small number of tornadoes observed in these "gap" periods could be due to several factors, both political and climatic. He also mentions that the number of reported tornadoes was relatively high during the last two decades of the 16th century. Due to the low number of cases before and after this period, there was either an increase in public interest in natural phenomena or the conditions were suitable for tornadoes during this period.

Brázdil [5] points out that starting in the 19th century the number of reported tornadoes began to increase quite steeply. In the 20th century, a total of 140 tornadoes were observed. Very few tornadoes were reported during the world wars and socialism because meteorological phenomena were largely ignored or perhaps "informationally regulated". Between 1948 and 1989, the use of the word "tornado" was even banned, both in meteorology and journalism. The two imaginary peaks in terms of the number of reported cases are the period between 1931 and 1940, when 44 tornadoes were reported, and the period between 2001 and 2010, when 56 tornadoes were reported. However, these two peak periods are likely more a reflection of available resources, increased interest from the general public, and the availability and improvement of communication technologies than increased tornado activity.

In terms of strength, most of the tornadoes that have occurred in the CR can be classified as tornadoes of a weaker nature (EF1). More than 60 EF1 tornadoes have already been recorded, with a total of more than 130 cases of probable tornadoes of EF1 strength then recorded. More than 40 tornadoes of both EF0 and EF2 strength have been observed. If we consider the cases of probable tornadoes, both intensities range at more than 60 cases. Stronger tornadoes of EF3 intensity have been observed in 20 [5].

In terms of the occurrence of tornadoes in the CR, it is possible to observe higher tornado activity in areas of low and medium altitudes. With the exception of mountainous regions located near the border, tornado occurrences are relatively evenly distributed across the entire CR. Thus, no region can be identified where tornado activity is unusually high. This is likely a reflection of the available resources from the areas in question. For example, records from the 16th to 18th centuries indicate higher tornado activity in the western region of the country, while the eastern region recorded relatively low tornado activity during this period. Both in the 20th century and in the period from 2001 to 2010, it is possible to identify relatively large areas of the country without an observed tornado occurrence. If we would like to characterize the locations of tornadoes in more detail, in most cases these are foothill areas or locations on the windward side of hills and uplands where airflow from the west occurs regularly [5].

Tornado activity was recorded in the CR from March to October. The earliest date of tornado occurrence is March 1, and the latest date on which a tornado was observed is October 13. Four probable tornado occurrences were also recorded during the winter months. The period of maximum tornado occurrence is during the summer months, from June to August. The probability of a tornado occurring in the country is higher in the spring months than in the autumn months. The vast majority of tornadoes have been documented in the late afternoon or early evening. A small number of cases were recorded in the early afternoon or late evening.

4. Tornado in South Moravia 2021

A severe thunderstorm warning has been issued for Thursday, June 24, in effect from Sunday, June 20 to Wednesday, June 23. However, meteorologists did not find sufficient potential for extreme thunderstorm activity. An increase in the storm danger level did not occur until 24 June 2021. The warning issued at midday on 24 June 2021 warned most of the CR of very severe thunderstorms advancing from Austria through southern Moravia and the Highlands further to the northeast from 5 p.m. on that day until 6 a.m. the following day, 25 June. The warning marked with a high danger level warned of very strong thunderstorms accompanied by torrential rain with local totals of around 50 mm, possible wind gusts of up to 90 km/h and hail with hail of larger sizes. The weather services of the neighbouring countries Austria, Slovakia and Poland have not issued extreme weather warnings either. In retrospect, the Czech Hydrometeorological Institute evaluated the success of the warnings issued for the districts of Břeclav and Hodonín as partially successful, especially in terms of hail size, i.e. instead of a high danger, an extreme danger should have been warned. While the tornado of 24 June 2021 struck southern Moravia at an altitude of around 150 to 200 metres above sea level, wind speeds reached around 400 km/h in the eye of the tornado. The highest wind gust at such low altitudes in the CR was measured in Znojmo and reached 173 km/h [11].

Other facts emerge from the text above. On 24 June 2021, after the merging of two storms on the Czech-Austrian border, a strong supercell formed, which continued to move northeast into the Czech Republic. The first effect of the supercell was severe hail, with hail averaging up to 10 centimetres in the area of Břeclav. Shortly after 5pm local time, a tornado formed east of Břeclav and headed further east across the D2 motorway. The tornado travelled 27.1 kilometres, causing damage in the villages of Hrušky, Moravská Nová Ves, Mikulčice, Lužice, the town of Hodonín and a location in the northern part of the cadastre of Hodonín and Pánovo. The tornado broke up at 17:53 local time south of the village of Ratíškovice. The duration of the tornado is therefore estimated at approximately 39 minutes. The maximum width of the tornado track was observed near Břeclav and reached 2 800 metres, the minimum width was then observed in Hodonin, where it reached 250 metres [12]. The tornado corresponded to the F4 classification according to Fujita's scale and maintained the character of a strong and dangerous phenomenon for almost the entire period of its existence. The vortex itself was moving at about 41.7 km/h. The path of the tornado and the nature of the damage throughout its existence can be seen in Figure 3.

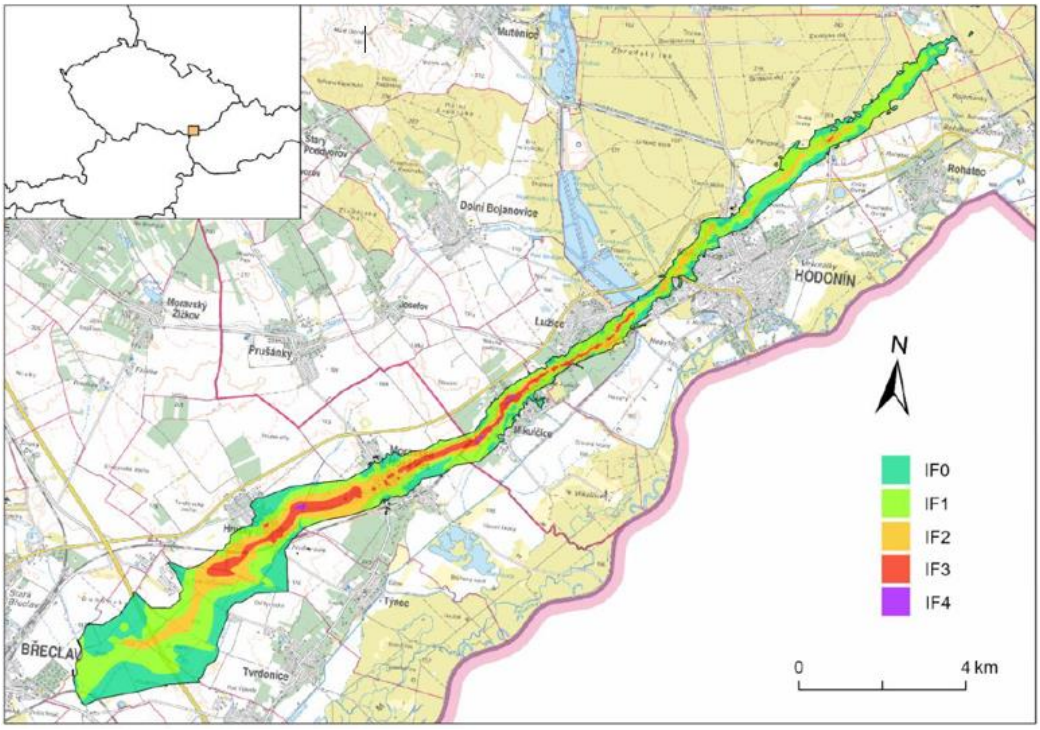

Fig. 3. The force of the tornado on the way from Břeclav to Ratíškovice [13]

During the tornado in South Moravia, 1,202 buildings were damaged, of which 180 buildings had to be either partially or completely demolished. According to preliminary estimates, the damage to private and public property was estimated at least 15 billion Czech crowns [14]. The tornado caused hundreds of injuries and unfortunately 6 fatalities. As already mentioned, the tornado affected the municipalities of Hrušky, Moravská Nová Ves, Lužice, Hodonín and Mikulčice. In the following, we will limit ourselves to more detailed specifications of the impact of the EE on the village of Mikulčice. We would like to add that, for example, the situation in Lusatia was also discussed in the book [15].

4.1. Mikulčice

4.1.1. Characteristics of post-event damage

The tornado was narrowing and gaining strength along the axis Moravská Nová Ves - Mikulčice. A total of 300 houses were damaged in the village of Mikulčice, 62 of which had to be demolished. In 3 locations the damage corresponded to the F4 classification. The most typical damage to the buildings were damaged roofs and collapsing ceilings, but some houses also showed significant damage to brick walls. The eastern end of the community was identified as the area of greatest tornado intensity. Here a 300 meter long tornado track could be observed. Damage along this path corresponded to an F4 classification. Several brick houses were completely destroyed in this area. The tornado also destroyed concrete noise barriers measuring 3 x 1 x 0.1 meters. The tornado also caused significant damage to a railroad track that was in the area. In particular, the railway catenary was damaged. Trees could be observed uprooted, broken or severely branched in the area of the tornado's greatest intensity. In Mikulčice, the tornado caused one loss of life.

From the point of view of the extent of damage and the organization of recovery in the municipality, it should be noted that the typical characteristic of F4 or F5 tornadoes, which were assessed in Mikulčice in this way, is extensive damage to property. This was no different in southern Moravia. From the message of the vice-mayor of Mikulčice, Eng. J. Vlašice [16], it follows that:

- total damage to municipal and regional property in Mikulčice was estimated at CZK 2.227 billion;
- restoration of damaged infrastructure and utilities (gas pipelines, heating and heat exchanger stations, electricity, telecommunications, etc.), restoration in the water and wastewater sector, (purification of drinking water sources, repairs of water and wastewater treatment plants, water pipelines, sewerage systems, etc.), restoration of transport infrastructure (repair of railway lines, roads, bridges, pavements, waterways and water transport systems, traffic signs, signalling equipment and public lighting, etc.) and ensuring the stability of damaged slopes with retaining walls, the necessary rehabilitation and restoration of public buildings providing basic functions for the population (especially in the areas of health, social care, education, civil protection, rescue and firefighting services, etc.) of the municipality of Mikulčice cost a total of CZK 107 million;
- almost half of the total amount (CZK 50 million) was spent on repairing damage to low, high and very high voltage distribution lines;
- the electricity was switched off for approximately one week in the entire village, after which the first sites began to be connected via temporary connections;
- the entire village was covered by electricity supply within two months;
- damage to the roads and pavements in the village was estimated at CZK 30 million;
- damage to public lighting amounted to CZK 15 million;
- the value of damage to traffic signs subsequently reached CZK 8 million;
- the value of damage to gas infrastructure was estimated at CZK 4 million;
- provision of protective measures during the state of danger and restoration of damaged or destroyed protective measures, provision, repair and strengthening (reinforcement of structurally disturbed or damaged structures of buildings, slopes, dams, dikes, river banks, culverts, etc.), diagnostic and geological surveys, immediate protection of cultural heritage, including restoration of basic functioning was valued at CZK 50 million;
- clean-up and rehabilitation of EE-affected areas and natural zones (including drainage, removal of mud, debris and other waste, landscaping, cutting and removal of damaged greenery, etc.), removal of contaminated soil and water, removal of structurally disturbed structures cost the municipality CZK 800 million;
- among the objects belonging to the municipal property, the damage to which has been estimated in the range of one to tens of millions of crowns, the Museum of Fanoš Mikulecký, the local cemetery, the cultural centre, the Homediss social services centre and the health centre, the multi-purpose playground, the scout clubhouse, the sports hall, the football field grandstand, the athletic complex, the municipal collection yard, the water treatment plant, the primary school, the kindergarten and the primary school canteen [17];
- the total damage to family houses, apartment buildings, vehicles, public buildings and similar objects was around CZK 1 billion and 200 million;
- temporary accommodation (of residents, soldiers, etc.), purchase of materials used to secure the crisis situation (e.g. sacks, sand, medical supplies, hygiene aids, etc.), rescue and liquidation (emergency) work provided by the regional authority, municipalities, fire rescue brigade (FRB), police, the Czech Armed Forces (CAF), medical rescue service

(MRS), etc. (the organisation of volunteer work, the restoration of destroyed or damaged equipment and the restoration of the ability to provide emergency services, hygiene and anti-epidemic measures cost the municipality approximately CZK 70 million.

Municipal greenery also suffered considerable damage. Damage to the local birch forest park alone was estimated at almost half a million crowns. However, the total damage to the municipal greenery certainly exceeded this amount, because although the birch forest park was located directly in the path of the tornado, it was still a relatively small area.

On this issue, we add that the restoration of municipal greenery should be one of the priorities of restoration works, because according to Kim et al [18], phytoremediation, i.e. the use of green plants to remove pollutants from the environment, where the plant absorbs pollutants in the air and degrades them based on its metabolic activities, is considered an ecological and cost-effective approach that helps to reduce air pollution. Uni [19] states that trees in communities can, depending on their location and planting density, capture some of the exhaust emissions from cars in the air. Mori [20] also notes that trees act as a physical barrier to prevent excessive movement of pollutants.

4.1.2. Implementation of population protection

Act No.239/2000 Coll. [21] characterises the population protection as the performance of civil protection tasks, especially in the field of warning, evacuation, shelter and emergency survival and other measures to ensure the protection of life, health and property. The Population Protection Concept [22] characterises population protection as: "A set of measures that help to ensure the protection of life and health of people, property and the environment. The tasks of population protection are performed not only by the components of the integrated rescue system (IRS), but also by the regional authorities, municipalities, legal entities and natural persons engaged in business, as well as by citizens themselves. It is citizens who very often forget that they have a shared responsibility for protecting their own lives and health and that of their loved ones." The comprehensive statutory concept of public protection is based on the diagram in Figure 4.

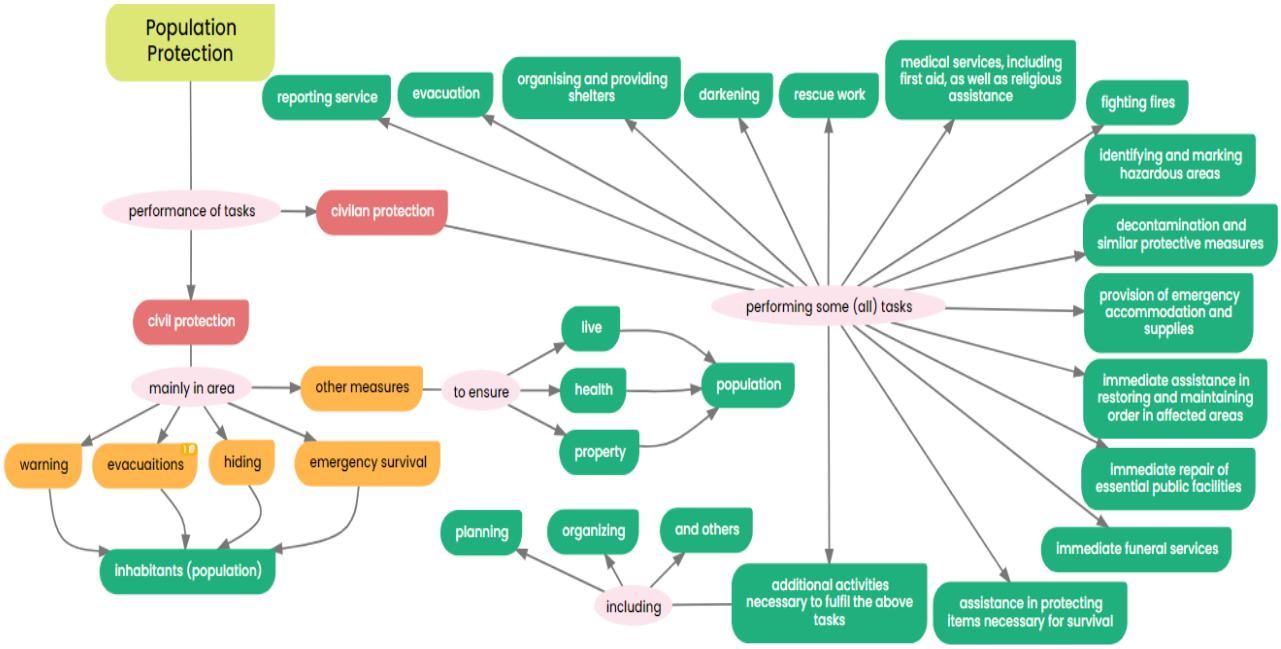

Fig. 4. Comprehensive statutory concept of population protection (own processing using ContextMinds [22])

During the first two hours after the event, 115 fire protection units, including 7 operational units, were dispatched to the tornado-hit areas. In total, 556 fire protection units were deployed to the affected area. 2 963 pieces of firefighting equipment were operating on the scene. A total of 7541 of personnel from the FRB intervened in the affected areas. FRB members carried out many different activities as part of the rescue, liquidation and demolition work. The most important ones include surveying the affected area, providing first aid, rescuing people from debris and vehicles, searching debris, extinguishing fires, dealing with gas leaks, clearing roads, removing debris and demolition. Very important tasks were also performed by specialists of the USAR (Urban Search and Rescue Team), which was activated in similar events beyond the use of all IRS units at the disaster site [23,24].

Due to the large number of incidents dealt with, it was necessary to prioritise the incidents within the operational management at the EE scene according to the reported threat to life and health of persons. The police officers on the scene mainly carried out initial actions aimed at saving lives and protecting the health of the inhabitants of the affected villages. Immediately after the EE occurred, the Police carried out several important activities. Among the activities important for the municipality itself, it is possible to mention the security of access roads, traffic control

and ensuring the passage of IRS units to the affected areas, cooperation in the establishment of a contact point for the IRS, the closure of the municipality to ensure public order and prevent looting, ensuring the prohibition of entry into structurally unstable properties until the arrival and decision of the structural engineer. On the basis of the request of the South Moravian Regional Health Service, the Police also closed the D2 motorway in the direction from Břeclav to Brno, which created a corridor for the possible transport of the injured and for the trouble-free arrival of all IRS units. The main activities of the Police during the days following the occurrence of the emergency included securing access roads, controlling traffic, ensuring the passage of emergency services, regulating the entry of vehicles into the closed affected villages, regulating the arrival of volunteers and humanitarian aid. Police officers also supervised public order, ensured security, prevented looting, enforced bans on entering structurally unstable properties until the arrival and decision of a structural engineer, guarded established car wrecking yards, landfills and places used to store construction materials for the restoration of damaged buildings. Other activities of the Police included guarding the property and equipment of the FRB, providing escorts for the heavy equipment of the IRS, deploying crisis interventionists to provide post-traumatic intervention care, monitoring and documenting the area with police drones and a police helicopter and, last but not least, providing information to the public by the Police using various information channels.

In the period from 24 June to 18 July 2021, i.e. the period until the end of rescue and liquidation work by the FRB, 9 672 shifts were served by police officers, of which 5 934 were day shifts and 3 738 were night shifts. During the entire period of the declaration of the state of danger, i.e. between 25 June and 23 August 2021, a total of 13 396 shifts were served by police officers, of which 8 073 were day shifts and 5 323 were night shifts. During the first few days, there was a maximum deployment of police officers on direct duty, with a total of 855 Police of the CR officers on the scene during the first 24 hours. As of 28 June 2021, an average of 260-270 Police officers were deployed in the area during the day and 190 officers during the night. From 8 July 2021, the number of Police officers on duty at the scene was gradually reduced as needed. From 6 September 2021, the deployment of police officers was reduced to 10 officers during the day and 10 officers overnight. The Police Air Service drones were also used at the request of the municipality to map the situation. During the EE, forces and resources from 9 regional directorates, the Police Air Service and the Police Pyrotechnic Service were deployed.

Due to the impassable roads (impassable or congested with cars) and therefore the impossibility of getting to the place of intervention, the MRS faced the worst situations in the villages of Mikulčice and Lužice. From the places affected by the tornado, the MRS, the transport ambulance service and the air ambulance service transported 83 patients. Of these 83 patients, 18 were transported from the village of Mikulčice. Exitus was found in 3 cases, none of them in the village of Mikulčice. No one died in the MRS ambulance. Due to the extent of EE, patients were transported to several hospitals. The highest volume of patients was at the Hodonín Hospital and the Břeclav Hospital, then patients were transported to Kyjov Hospital, Uherské Hradiště Hospital, St. Anne's University Hospital in Brno, Brno University Hospital, Children's Hospital of the Brno University Hospital, Brno Trauma Hospital and the Military Hospital Brno. Two patients were transported by air ambulance to the Vienna General Hospital and the Donaustadt Clinic in Vienna. Due to the meteorological situation in the CR, it was not possible to send any air ambulance service from the CR to the scene.

A total of 43 vehicles (2 to 5 employees), a vehicle for emergencies - MB ATEGO, a vehicle for intervention in the field - Toyota Hilux and a vehicle for the biohazard team intervened in the affected area. In the affected area, 47 resources not falling under the South Moravian Region Rescue Service also assisted. Specifically, there were 2 ambulances from the Zlín Region, 4 ambulances and 4 ambulances from the Vysočina Region, 2 ambulances and one ambulance in the rendez-vous system from the Pardubice Region, 4 ambulances from the Olomouc Region, 7 ambulances from the Bratislava Region, 4 ambulances from the Trnava Region and 2 rendez-vous ambulances, 15 ambulances and 2 air ambulances from Austria.

In the sector defined by the municipalities of Mikulčice and Lužice, one ambulance, one rendez-vous ambulance and one emergency vehicle - ATEGO (ambulance) have been present since the start of the liquidation work. At night, one ambulance and one ATEGO emergency vehicle were present. From 27 June to 2 July, the trauma team of the University Hospital Brno was also available, which, among other things, managed the COVID-19 collection point for the intervening IRS units. From 25.6. to 7.7. (the period of activity within the liquidation works) 254 treatments were registered at the Mikulčice dispensary.

The first members of the CAF arrived at the EE site the day after the tornado occurred, on 25 June 2021. The primary task of the CAF units was, in accordance with the requirements of the FRB and the Governor of the South Moravian Region, to assist with liquidation work in the villages. For this purpose, CAF equipment, such as army dozers, loaders, Tatra trucks and trailers, were also deployed. In total, 91 pieces of equipment belonging to the administration of the CAF were deployed at the site of the emergency. In addition to the liquidation work, the members of the CAF also helped the citizens of the villages with the initial reconstruction of their homes and in the village of Mikulčice they helped with the work in a temporary warehouse for building materials.

Non-affected citizens also played a certain and significant role in the reconstruction, helping in the restoration of both municipal and private property, in work related to the provision of humanitarian aid, and in the temporary construction material warehouse and in cleaning the village. Another important component involved in the liquidation and reconstruction of the village were the volunteers, who came to the village from almost all over the CR. It can be estimated that there were two to three times the usual number of inhabitants in the village, i.e. about 4 000 people helping. The highest estimate of the number of volunteers who helped in the village is as high as 6 000.

5. Brief Insight into the Implementation of the Research Investigation

The research survey was conducted in the form of an anonymous online questionnaire. The content of the questionnaire was consulted with a member of the FRB from the Population Protection Department. Furthermore, the questionnaire was consulted and tested with an IT consultant from Arkance Systems. The questionnaire contained both open and closed questions. The questionnaire also included questions where the respondent expressed their level of satisfaction on a scale from "very satisfied" to "very dissatisfied". The variety of questions was intended to increase the quality of the research, and the questions were asked in a clear, simple and easy way for answer. A total of 64 respondents took part in the survey, with a ratio of 70.3% women (45 respondents) to 29.7% men (19 respondents). Women made up more than two thirds of the respondents. The questionnaire was distributed only among the citizens of Mikulčice.

6. Research Conclusions and Design Measures

Please note that the sociological research was conducted 2 years after the tornado occurred. The answers of the citizens would very likely be different compared to the time just after the occurrence of EE. In contrast to the results obtained in early 2023, when citizens, for example, evaluated almost all of the IRS units involved in rescue, recovery, and restoration work positively, they may have expressed themselves more negatively in the period immediately following the occurrence of the tornado, given the psychological pressure that the occurrence of the tornado brought, for many reasons. However, in the period immediately following the tornado's occurrence, it would also have been relatively more difficult to obtain responses from citizens who were immediately affected given that they were still dealing with the aftermath of the EE.

The research conducted showed that:

- the village of Mikulčice should have bn better prepared for EE in the form of a strong tornado. However, is it possible to prepare effectively for an EE of this magnitude, moreover, if this phenomenon is very unlikely in a given location? This question will undoubtedly be a food for thought not only for the representatives of the Mikulčice municipality, but also for the relevant crisis authorities at the level of the municipality with extended competence and the region;
- despite the opinions that strong tornadoes are a phenomenon that is not common in the CR, they are discussed in many scientific papers. It turned out that most of the respondents of the questionnaire agreed with this theoretical opinion. Despite the constant need to develop knowledge about how to behave in the event of a EE, most respondents indicated that they now have an understanding of how to behave in the event of a severe tornado. In our opinion, it is still appropriate to continue to inform the general public about this issue and to use the experience in the form of, for example, lessondrilled;
- it's very difficult to determine the strength of a tornado using wind speed. The most common indicator of tornado strength is usually the aftermath, i.e. the damage. The fact that a very strong tornado formed in South Moravia is confirmed by the results of the questionnaire, where two thirds of the respondents stated that they had been personally affected by a tornado. Almost all of these respondents suffered some damage to their property, and more than half of them then suffered property damage exceeding one million crowns;
- the assumption that a minimum number of respondents had information about an approaching tornado was confirmed, despite the fact that the definition of public protection states that one of the main tasks of public protection is warning and evacuation in the event of danger;
- during the EE a large number of IRS officers were deployed in the affected area. It can be concluded that the IRS did a professional job, as most respondents reported a high level of satisfaction with its components. Specific examples of the management of the situation could include the fact that the police maintained a high level of security in the village and managed relatively well to control the traffic situation in the village;
- despite the enormous damage in the village, the citizens are convinced that the reconstruction in the village is going fast enough given the situation and they are satisfied with the ongoing reconstruction as far as possible;

The article pointed out and respondents confirmed that the municipality of Mikulčice could have been better prepared for a large-scale EE. The municipality's leadership should view the rebuilding of the municipality as an opportunity to better prepare for a similar event, and not just as a simple rebuilding of destroyed or affected buildings. Since Mikulčice has in the past prepared mainly for threats that can be expected in South Moravia (e.g. floods), the crisis plan should be updated to include the possibility of a severe tornado. We believe that the representatives of the Mikulčice municipality should initiate cooperation with municipalities affected by a similar EE, and on the basis of shared experience, crisis plans could be regularly and effectively renewed. In order to accomplish this task, we suggest that the impacts of this EE on the Hodonín micro-region be analysed in detail in the context of the impact on the crisis planning of the Hodonín town.

Furthermore, we propose that the possibilities for the implementation of emergency shelter and survival of the population of the Mikulčice municipality be reassessed. In the event of a recurrence of a tornado within a relatively short time after its occurrence in 2021, it is very likely that the capacity of the municipality would have to be used to a much greater extent than it was in 2021. The questionnaire distributed to the residents of Mikulčice also shows that

some citizens are not satisfied with the quality of the accommodation provided to those affected. Therefore, the municipality should consider contracting higher quality accommodation facilities if such facilities are available in the vicinity of the municipality.

A major problem during the occurrence of the tornado and the recovery was the total loss of electrical power. In the village of Mikulčice, power supply wires were routed through the air during the tornado. For this reason, the damage to this infrastructure was very high. When rebuilding the village, we suggest that the possibility of placing the high and low voltage power lines underground be considered. Even knowing that the maintenance of technical equipment stored in this way could be more difficult, we believe that this is the best solution in terms of its resilience. Damages would not be as high in a similar situation to 2021 and it is likely that interruption of power supply to any part of the community could be avoided. A questionnaire distributed to the residents of Mikulčice shows that underground cabling would also be preferred by the majority of citizens.

Since the power was out before the tornado struck Mikulčice, citizens could not be warned of the impending danger via the municipal public address system. It is therefore necessary to start preparing the upgrading of the means of alerting, warning and informing the inhabitants of the village by means independent of the immediate electricity supply. A very suitable solution would be to provide back-up power for the warning and alert systems, a public address system, a wireless radio or, alternatively, a radio with cable distribution in the ground. In the context of the development of cellular networks and new data technologies, we suggest that the municipal leadership allocate funds in its strategic financial plan to secure long-term leases of cellular carrier stations and signal scramblers from cellular operators.

As part of preventive educational actions aimed at raising awareness of public protection, we suggest that the municipality's leadership consider organizing and holding thematic lectures or seminars focused on how to behave in the event of a large-scale EE (such as a tornado or other similarly large-scale EE). Subsequently, it could be mentioned how the municipality could help the affected citizens in case of an EE. Among the topics that could be the starting point for starting to think about this issue, we suggest, for example, topics that could be framed as:

- climate change and its impact on regions;
- measures for the protection of the population and the possibilities of its implementation after the occurrence of a large-scale EE on the territory of the Mikulčice municipality;
- impacts of natural extremes on the landscape and population;
- possibilities of cooperation of the population with the IRS units in dealing with the consequences of EE;
- rules and standards for the use of volunteer assistance by the inhabitants of the municipality.

We suggest that the topics mentioned above be explained in appropriate form and with appropriate methods and forms to pupils in the primary schools in Hrušky, Moravská Nová Ves, Mikulčice, Lužice and Hodonín, i.e. in the municipalities that were directly affected. In the form of appropriate methodological working aids, to act as a preventive measure and not to deter from the facts that natural influences and their extremes can bring at present.

We further recommend that the municipal management initiate intensive work leading to the contracting or lending of specific items for EE recovery. The immediate preparedness of the municipality during the first days/weeks immediately after the EE has proved to be irreplaceable and some types of material were acutely lacking. Examples of such items include power generators and gas cookers. Should a similar situation recur, and moreover during the winter months, it can be assumed that the provision of resources to ensure the operational generation of thermal power would become an absolute necessity.

Furthermore, we propose that work be started on a model activity of the IRS components in a joint intervention, which could bear the working title: “STČ XX/IZS Tornado Emergency”.

Despite the fact that practically half of the respondents expressed that they agree with the approaches of the municipality's leadership to dealing with the consequences of EE associated with the occurrence of a tornado in the municipality of Mikulčice in 2021, it is necessary to note some fundamental aspects that can be quite a limitation on the one hand and a challenge on the other hand in the next period. Among these I include in particular:

- the current possibilities of the current public budgets;
- the mood of the population in relation to the threats arising from the current security situation in Eastern Europe.

We consider it essential that the needs of the community are integrated not only in relation to the threats experienced or potentially possible, but also to situations that have a supra-regional or even international scope. I consider the ability of the municipal leadership to see ahead in terms of safety and security, to anticipate and assess the realistic possibilities of financial budgets to be absolutely essential.

7. Conclusions

Dealing with the consequences of EE, which are not a normal part of the crisis management activities of a municipality, municipal district, region or even the state, is not a simple matter. The authors of this communication are sufficiently aware that the training of response to EE, which are very difficult to predict in advance, is a very difficult and basically unfeasible matter. Furthermore, we are aware that there is not enough experience to date that could be passed on for further evaluation in the form of tactical procedures, typical activities of IRS units, lessons learned, etc. We are aware that the time that has elapsed since the EE may have been a limit to the acquisition of relevant information. Since the authors' efforts were motivated by the desire to obtain information on the functionality of the

systems at a time when rescue and disposal work, usually associated with great enthusiasm and determination of the intervening personnel and volunteers, was completed, we do not consider this shortcoming to be a handicap, but rather an advantage. We base this statement on the fact that the draft measures, which were based on a questionnaire survey and the retrospective assessment of the situation by the inhabitants of the village themselves, are more relevant than ad-hoc opinions expressed under the influence of strong emotions.

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