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B-PREPARED TO SURVIVE DISASTERS IN INDUSTRIAL ENVIRONMENTS

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This paper presents novel application possibilities in industrial environments based on the experiences of disaster events, using the ecosystem of the B-prepared Horizon Europe project. The most important task of the project is to offer novel and effective solutions to prepare EU citizens for disaster situations. This topic addresses safety and resilience as priorities of EU policy. To achieve this goal, we process past disaster events and create various gamified services that are available to interested participants in an interactive and playful form. This solution uses a richly populated community knowledge-sharing portal and offers products available on multiple platforms: web, mobile, Augmented Reality (AR), Virtual Reality (VR). The applied approach is the theory of psychological vaccination, also known as stress vaccination training, a promising proactive tool used to prepare the population for disasters, and focuses on the preliminary strengthening of resilience and coping skills. The content packages available in each product are parts of a model used in a dedicated solution development process and for preparing all actors facing future hazards and disaster situations, which also occur during industrial production and manufacturing. The experiences gained during the completion of the project and the implemented B-prepared Ecosystem comprise a strong and reliable resource for this approach.

Keywords: disaster preparedness, game-based tools, B-prepared, Horizon Europe, citizen survival, QALY

1. Introduction

This paper presents the B-prepared Horizon Europe project [1], which offers a cost-effective solution for building a culture of disaster preparedness with a multi-actor approach in realistic historical scenarios. The project, launched in October 2023, is carried out by a consortium of 15 renowned European organizations. The consortium is led by HUN-REN Institute for Computer Science and Control (HUN-REN SZTAKI), and the project runs for 3 years. We also present how the B-prepared Ecosystem can be applied to prepare citizens for disaster situations in factory and other industrial environments based on the experiences of past hazards and catastrophes.

Recent disasters have demonstrated that even the most advanced warning systems and highly trained first responder organizations cannot fully prevent deaths or significant property damage unless citizens are properly prepared, by knowing how to respond in emergencies, understanding alerts, and following instructions.

It is among the EU's policy priorities to build "A resilient EU prepared for emerging threats". Europe has seen major floods and forest fires, and record-breaking heatwaves have become commonplace in the past decade. As a result of climate change, the intensity and frequency of disasters are expected to increase further.

Current institutionalized practices, as outlined in the ISO 22398 standard [2] on societal security exercises, typically demand substantial financial and human resources, carry significant risks, and are limited in their ability to reach a large number of citizens or to be repeated frequently. The current digital educational technologies can transfer the knowledge and skills required to survive and manage both natural or human caused disaster situations at significantly lower costs.

Most of the EU-funded projects on preparedness for disaster situations target first responders. The general approach of these solutions is that citizens are treated as

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a large and diverse group that is the subject of first-responder efforts. The unique feature of the B-prepared project is its citizen-centric approach. It is critical in the disaster that people possess basic survival skills before first responders arrive and save everyone.

National differences significantly affect individual preparedness behavior and awareness of risks [3],[4]. The aim of our project is to increase citizens' preparedness using virtual reality and gamification by addressing specific needs, in both location-based and situation-based cases. As indicated above, and in comparison with previously published efforts, our proposed solution will achieve not only individual national results but also joint international outcomes, incorporating new information and communication technology (ICT) features and tools, as well as integrated e-learning technology with virtual reality and gamified services.

The remainder of this paper is organized as follows. Section 2 presents the project. Section 3 provides an overview of the B-prepared Ecosystem formed by interconnected B-prepared products. Section 4 lists disaster events related to industrial environments that are already presented in the B-prepared project. Section 5 discusses measurement methods that can be used to estimate the economic benefits of our approach. Section 6 concludes the paper.

2. The B-prepared project

The B-prepared Horizon Europe project is being completed by a consortium of 15 renowned European organizations from 11 EU Member States and associated countries across Europe. The project was launched in October 2023 and runs for three years. The consortium involving first responders, high-tech enterprises, research organizations and academic institutions is being led by HUN-REN SZTAKI in Hungary.

The main objective of the project is to offer innovative and effective solutions to prepare EU citizens for disaster situations. To achieve this goal, past disaster events are processed, and various gamified services are created that are available to interested participants in an interactive and playful form. This solution uses a richly populated community knowledge-sharing portal and offers products available on multiple platforms, including Web, mobile, Augmented Reality (AR), Virtual Reality (VR). An iterative development, testing, integration and refinement process was applied to create the B-prepared content and software components. We strive to involve all relevant stakeholders, including citizens, civil society and end users in the co-creation of content.

The value proposition of the B-prepared project compared with other projects lies in its integrated approach and the use of innovative technologies to engage citizens. The project offers different platforms integrated with each other for users to acquire new knowledge and skills. The project combines technologies and methodologies such as serious games, a gamified mobile application, a knowledge-collaboration platform, and a Learning Management System (LMS). The project strongly exploits the advances in serious games and VR, which offer promising new opportunities for emergency preparedness training.

Scenarios and missions are used to train relevant activities in emergency situations and include training on how to help others in need.

The applied approach is the theory of psychological vaccination, also known as stress vaccination training, a promising proactive tool used to prepare the population for disasters, and focuses on the preliminary strengthening of resilience and coping skills. The project presents a wide range of historical disaster events, which raise awareness of potential risks, lead to understanding the importance of preventive measures, and motivates users to prepare for disasters.

The content packages available in each product are parts of a model used in a dedicated solution development process and for preparing all actors facing future hazards and disaster situations, which may also occur during industrial production and manufacturing.

3. The B-prepared Ecosystem

3.1. Overview

A collaboration and co-creation ecosystem was created in the B-prepared project to enhance citizen preparedness for disasters and crises via serious gaming, gamified e-learning, and knowledge sharing. It represents a major advantage compared to other state-of-the-art solutions where disaster preparedness training is usually restricted to a single platform. Location-based and gamified mobile applications and VR serious games based on content created and supported by collaborative knowledge management platforms provide an immersive and realistic experience (*Figure 1*). The open beta version of the products will be freely available from April 2026. The following subsections discuss the four main components of the B-prepared Ecosystem which can be extended with third-party solutions in the future.

3.2. Disastropedia

Disastropedia represents an online encyclopedia of disaster-related knowledge (*Figure 2*). It supports other components by collecting and supplying disaster-related content and game design generated collaboratively by the Co-Creation Community Group of experts. It can be connected with third-party components via application programming interface (API). The users can obtain valuable information on disaster preparedness in a structured format, and they can also create new content on the platform. It currently has about 700 registered users. The platform is open to new users. The community can be joined at the following link: https://disastropedia.com/.

Figure 1: The B-prepared Ecosystem consisting of four main components

3.3. VR-prepared

VR-prepared application is a virtual reality-based multiplayer cooperative serious game designed to provide a safe and highly realistic experience (*Figure 3*). It offers an immersive learning experience through a variety of disaster preparedness scenarios. This innovative approach aims to engage users in realistic simulations, equipping them with the knowledge and skills needed to effectively respond to emergencies. It includes two scenarios: Forest Fire and King Tide. The VR game is currently available for registered closed beta testers (registration is open on the website) but after May 2026 until end of September 2026, the open-beta version will be available freely in the Epic Games Store.

3.4. IM-prepared

The IM-prepared application offers gamified, GPS-based smartphone walks to ensure the widest possible reach (*Figure 4*). The IM-prepared mobile application is designed to enhance disaster preparedness through interactive walks. These walks are crafted to engage citizens in a variety of activities that simulate real-life disaster scenarios, offering a blend of educational content, mini-games, microlearning quizzes, and AR activities. The application can be freely downloaded from the most popular mobile application stores (Google Play and Apple App Store) under the name IM-prepared.

3.5. RU-prepared

The RU-prepared module includes a learning management system to measure progress in all products. RU-prepared provides e-learning content in a responsive and accessible interface. It is integrated with other B-prepared components and it can measure preparedness level achieved by VR-prepared and IM-prepared on a unified scale. Citizen-centered curricula and courses on disaster preparedness will also be created.

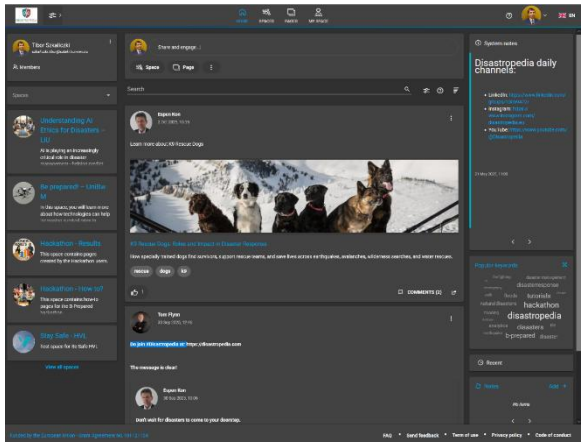

Figure 2: Screen from Disastropedia

Figure 3: Screenshot from VR-prepared

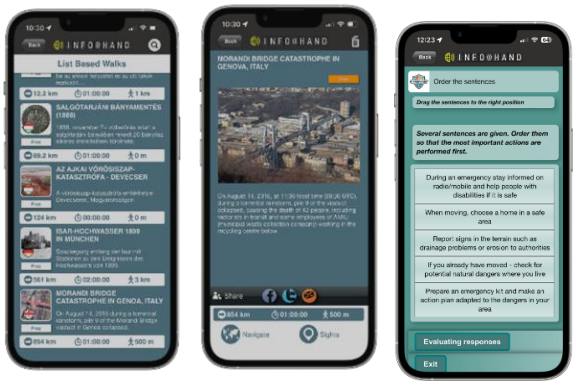

Figure 4: Screenshots from IM-prepared

4. Applications in industrial environments

The B-prepared project already presents past disaster events related to industrial environments. They can serve as an example for further content in manufacturing and industrial environments.

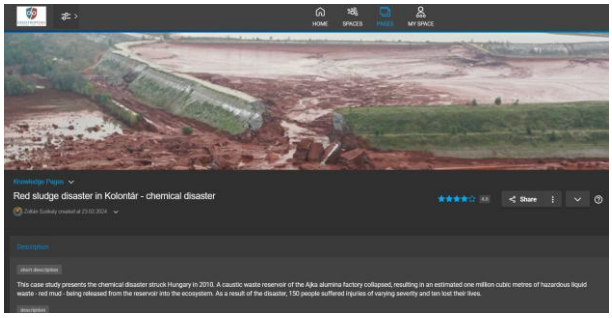

Figure 5: Red sludge disaster presented in Disastropedia

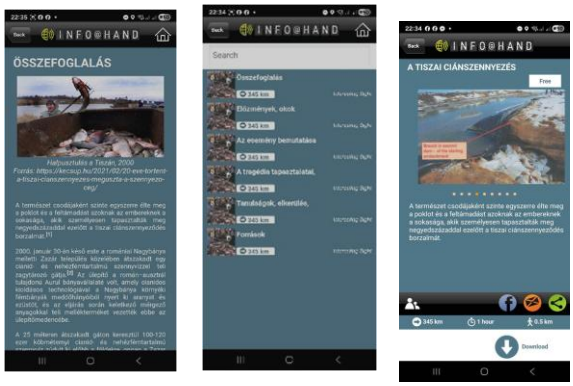

Figure 6: Screenshots from the IM-prepared walk on cyanide pollution in the Tisza River

4.1. Chemical disaster triggered by a landslide

The red sludge disaster in Ajka, Hungary

A chemical disaster struck Hungary in 2010. The dam of a caustic waste reservoir of the Ajka alumina factory collapsed, resulting in an estimated one million cubic metres of hazardous liquid waste – red mud – abeing released from the reservoir into the geoecosystem. As an outcome of the disaster, 150 people suffered injuries of varying severity, and ten lost their lives.

Red sludge is produced during the alumina production process known as the Bayer process, and is a mixture of powder and liquid remaining after the sodium hydroxide treatment (cooking) of ground bauxite powder. It is a strongly alkaline (pH typically 10–11, but it was 13 in the lye reservoir), mud-like substance with 40-45% moisture content. It gets its red color from the iron oxide that remains in it.

The disaster is presented both on Disastropedia and the IM-prepared mobile application (*Figure 5*). The disaster event, its consequences and the response are described. The mobile application includes a list-based walk in Hungarian and English languages including points of interest (POIs) related to the disaster in Devecser, near Ajka.

4.2. Mining

Cyanide pollution in the Tisza River, Romania-Hungary

In 2000, near the settlement of Zazar, close to Baia Mare in Romania, the dam of a tailings pond filled with cyanide- and heavy-metal-contaminated wastewater, burst open. The settling pond belonged to a mining company, which used cyanide leaching technology to extract gold and silver from the waste heaps of the metal mines around Baia Mare. The toxic by-products generated during this process were discharged into this settling basin. Through the 25-metre-wide breach, 100,000–120,000 cubic metres of cyanide- and heavy-metal-contaminated wastewater first flooded the surrounding land, then flowed into small rivers, and subsequently into the Someş River and then the Tisza. A 40–50-kilometre-long contamination plume entered Hungary. The concentration of toxic substances exceeded the permitted limit by a factor of 180, causing devastating damage to wildlife.

An IM-prepared list-based walk describes the background, the disaster event, experiences and lessons learned, and how to prevent similar catastrophes (*Figure 6*). Presenting the disaster draws attention to the risks associated with outdated technologies, the need to renovate aging or obsolete facilities, to review occupational safety regulations, and to implement modern monitoring systems.

Mine rescue in Salgótarján, Hungary

In 1888, 20 miners were trapped in the Salgótarján mine (Hungary) due to a water inrush. They spent 56 hours underground before they were successfully rescued.

An IM-prepared list-based walk describes the water inrush, the rescue operation, the restoration of the mine and lessons learned. The response to this disaster demonstrated the effectiveness of rapid rescue operations. Lives can be saved through right and swift managerial decisions and a sense of responsibility, and the danger can be reduced through self-sacrificing efforts.

4.3. Transportation

Morandi Bridge collapse in Genoa, Italy

The Morandi Bridge collapse occurred in 2018, in Genoa, Italy, when a large section of the Polcevera Viaduct, part of the A10 motorway, suddenly failed during a storm. The collapse resulted in 43 deaths, dozens of injuries, and significant infrastructure damage. Built in the 1960s, the cable-stayed bridge had long been criticized for structural weaknesses.

The disaster is presented both in Disastropedia and the IM-prepared mobile application (*Figure 7*). The construction of the bridge, its design and features, the collapse, the victims, the response by emergency services, and the bridge memorial are described. The mobile application includes a list-based walk in English about the catastrophe.

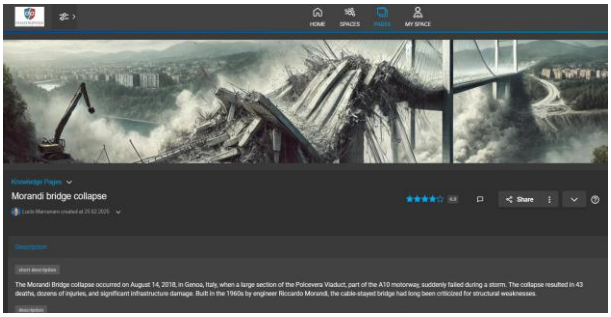

Figure 7: The Morandi Bridge collapse presented in Disastropedia

Figure 8: Screenshots from the IM-prepared walk about the fire at the Budapest University of Technology and Economics

4.4. Entertainment

Fire at the shooting range at the Budapest University of Technology and Economics, Hungary

In 2006, a fire broke out at the shooting range located on level -2 of the central building (the so-called K Building) of the Budapest University of Technology and Economics. A total of 130 firefighters took part in extinguishing the blaze on site. During the rescue operations, three firefighters lost their lives, and seven others suffered smoke inhalation.

An IM-prepared list-based walk describes the circumstances of the fire, the rescue operations, the findings of the investigation report, and its remembrance of the event (*Figure 8*).

5. Measuring economic benefits related to better disaster preparedness

When making public investment in disaster preparedness, estimating the expected returns on investment is key in legitimizing decision-making. The most important factor is, of course, averting the loss of lives and damage to health and property. In case of damage to property, calculating the costs of rebuilding is usually not excessively problematic, but establishing a commensurable metric regarding the value of human life, taking into account the dimensions of well-being and longevity, is a more challenging task. Our project offers an innovative, experimental approach in this regard, as it pioneers the use of the Quality Adjusted Life Years (QALY) metric for measuring the expected cost-benefit ratio of providing disaster resilience training to citizens.

QALY [5] is a measure of health outcomes that combines both the quantity (length) and quality of life into a unified value. It is calculated by multiplying the number of life years by a health-related quality of life score, which is on a scale between 0 (dead) and 1 (perfect health). QALY is a conventional valuation method used in health policy widely used in economic evaluations to assess the cost-effectiveness of medical treatments and interventions. Its main benefit is that it is able to transform health-related outcomes into monetary terms, despite its inherent limitations, and thus it enables meaningful cost-benefit analysis (CBA) before public policy-making. It is crucial that this approach is being used as an experimental valuation method by our project, which investigates the applicability of the metric for the field of disaster resilience. There are various limitations to the approach, chiefly related to empirical data collection. The availability of empirical data on the estimated QALY value associated with a disaster resilience enhancing intervention is severely limited. Therefore, bridging this gap is crucial for our project and for further research. We ought to establish sound methodologies to gather meaningful empirics on how disaster resilience training affects the citizens' QALY values. However, we did find some pre-existing data. A US-based study found that “CPR/defibrillation training of laypersons yielded 2,7 quality-adjusted hours of life” increase [6]. Our project then used this value to establish the conceptual legitimacy of the approach and to create a preliminary cost-benefit estimation. Thus, we computed the expected returns on investment of the B-prepared project using a range of monetary values associated with QALYs following European research projects in the field [7].

Using this experimental valuation approach, we estimate that while developing VR and AR based training for disaster resilience implies significant initial investment costs, overall, the cost-benefit ratio of virtual, serious game-based training is much more beneficial compared to real life drills. After all the reach of virtual training can be significantly higher, moreover, the possibility of revisiting the training anytime and anywhere makes it easily accessible and practical. AI-based interactivity, personalization and gamification capacities ensure relevance and engagement, while the scenario (although virtual) is still able to convey knowledge and experience in a meaningful manner. Investing in a live drill remains beneficial, but it is limited in space, time and reproducibility. Therefore, according to our valuation method using QALYs, serious game-based virtual scenarios such as those developed by the B-prepared project yield a better cost-benefit ratio and better returns on investment.

6. Conclusion and plans

B-prepared provides an affordable way to foster a culture of disaster preparedness through a multi-actor approach using realistic historical scenarios. The open beta versions of the B-prepared products will be publicly available, and stakeholders will be invited via direct outreach. The B-prepared ecosystem can play a crucial role in enhancing citizen preparedness for hazards and crises that also represent real threats in industrial environments. This approach empowers citizens to become active participants in disaster preparedness. The lessons and results presented here are still at the initial phase, and through the dissemination of the project idea, we expect to receive a large amount of feedback to generate a pool of lessons worth remembering. The project consortium is open to collaboration with stakeholders interested in joining the testing of the products or adding B-prepared to their regular training, drills or exercises.

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