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Overview of the application requirements of metaverse on emergency management in chemical industrial parks

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Technical Report ITU FGMV-30

Overview of the application requirements of metaverse on emergency management in chemical industrial parks

Summary

Chemical industrial parks, as the main sites of chemicals and chemical production, are confronted with a high safety risk. Once an accident occurs, it may result in large-scale loss of life and property. However, the application of metaverse can improve the efficiency of risk management and emergency management in chemical industrial parks. This Technical Report introduces the application requirements and scenarios of metaverse in emergency management within chemical industrial parks. The aim is to identify metaverse platform requirements and address potential issues, as well as enhance the emergency response capability of responders in chemical industrial parks.

Keywords

Metaverse; Chemical industrial parks; Emergency management; Application

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains Version 1.0 of the ITU Technical Report on "*Overview of the application requirements of metaverse on emergency management in chemical industrial parks*" approved at the 6th meeting of the ITU Focus Group on metaverse (FG-MV) held virtually on 30 April 2024.

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Additional information and materials relating to this report can be found at: https://www.itu.int/go/fgmv. If you would like to provide any additional information, please contact Cristina Bueti at tsbfgmv@itu.int.

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Overview of the application requirements of metaverse on emergency management in chemical industrial parks

1 Scope

This technical report provides application requirements of metaverse of emergency management in chemical industrial parks (CIPs), so as to address the potential risks and strengthen the emergency response capability in the chemical industrial parks. The scope of this document is as follows:

– Fundamental requirements of emergency management in CIPs.

– The metaverse platform requirements of emergency management in CIPs.

– Application scenarios.

2 References

None.

3 Terms and definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.2 Sensor [b-ITU-T Y.4113]: An electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic.

NOTE – Examples of usage of sensors include temperature monitoring, gas-leak alert, traffic congestion prediction, earthquake early warning, etc.

3.1.3 Metaverse [b-ITU-T FG-MV-20]: An integrative ecosystem of virtual worlds offering immersive experiences to users that modify pre-existing and create new value from economic, environmental, social and cultural perspectives.

3.1.3 Virtual Reality [b-ITU-T P.1320]: An environment that is fully generated by digital means. To qualify as virtual reality, the virtual environments should differ from the local environment.

3.2 Terms defined here

None

4 Abbreviations

CIPs	Chemical Industrial Parks
IoT	Internet of Things
VR	Virtual Reality
PII	Personal Identifiable Information

5 Conventions

In this document:

– The keywords "**is required**" indicate a requirement that must be followed strictly and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

– The keywords "**is recommended**" indicate a requirement that is recommended but is not absolutely required. Consequently, this requirement need not be present to claim conformance.

6 Fundamental requirements on emergency management

The metaverse describes a virtual space where people can interact and communicate with each other in an immersive and interactive way. Metaverse is evolving rapidly and has the potential to revolutionize the way emergency situations are managed in the chemical industrial parks (CIPs). This clause examines how the metaverse can be used to improve emergency management in CIPs.

CIPs contain complex facilities that are home to a variety of chemical processes and operations. Given that the inherent risk of accidents and emergencies in such environments, it is highly dangerous. Consequently, emergency management in these facilities is critical to ensuring the safety of workers, the surrounding environment, and the local communities.

6.1 Overview of emergency management of chemical industrial parks

Chemical industrial parks (CIPs) are specialized zones which contain a diverse range of chemical companies exclusively dedicated to the chemical industry. These parks are professionally managed sites that provide chemical companies with comprehensive services, enabling them to concentrate on their primary business activities. Leveraging exceptional infrastructure and shared services within the parks, CIPs aim to streamline operations and facilitate efficient business operations within the chemical sector. This management style means to enhance energy and resource efficiency, environmental performance, and economic competitiveness.

However, As a high concentration of those hazards in a limited space,CIPs will cause a chain reaction in the event of an accident. Once a security accident happens, it may result in large scale loss of life and property.Thus, emergency management in CIPs requires proactive measures, as Figure 1 shows , the emergency management in CIPs is a complex work , which requires the collaboration of the Special Equipment Supervision and Inspection, Emergency Communications, Emergency Management, Environmental Emergency Monitoring , and Medical Emergency .By establishing robust systems, fostering partnerships,the managers in CIPs can enhance their ability to respond effectively to emergencies and mitigate potential risks.

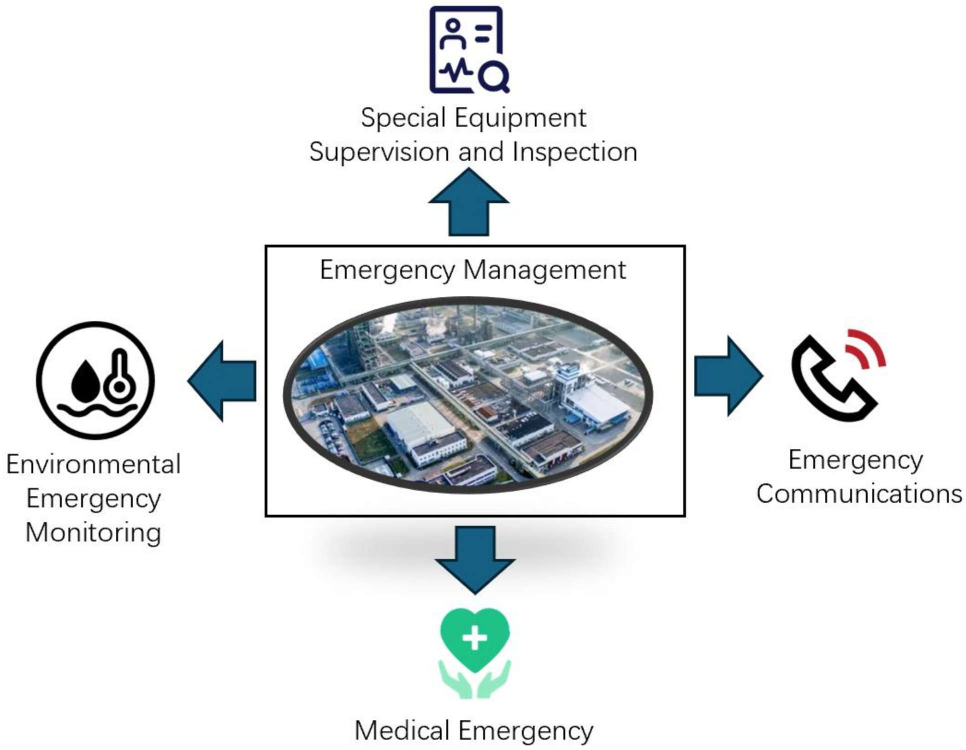

Figure 1-Emergency management in CIPs

6.2 A platform for immersiveand effective communication

One of the most significant challenges of emergency management in CIPs is the requirement for quick and effective communication. During an emergency, if emergency responders can get to the accident sites in time and provide a quick response, the domino effect will be controlled and the losses through accident will be greatly reduced. Therefore, the ability to communicate quickly and efficiently can make all the difference. Metaverse can provide a platform for immersive and real-time communication; it enables rescue teams to collaborate seamlessly between emergency responders and other stakeholders such as facility operators and local authorities.

6.3 Access to real-time data and evaluate risks

With the use of metaverse, emergency responders can have access to real-time data and information about the situation, including sensor data from various parts of the facility and can conduct risk-free explorations in the metaverse platform. These explorations can help emergency responders make informed decisions about how to respond to the emergency and minimize the risk of further harm. Additionally, the use of virtual reality (VR) technology can provide emergency responders with a realistic representation of the facility, enabling them to navigate and make decisions in a controlled environment.

6.4 Simulated emergency situations

The benefit of applying metaverse in emergency management is the ability to simulate emergency situations. Before an emergency occurs, facility operators and emergency responders can use these technologies to simulate different scenarios and test their response strategies. This can help identify potential shortcomings in emergency plans and procedures, allowing for improvements to be made before an actual emergency occurs.

7 The metaverse platform requirements of emergency management in CIPs

Chemical industrial parks are vulnerable to emergencies due to their potentially hazardous materials. A metaverse platform offers a virtual world that simulates the physical world, allowing employees to interact in a virtual environment with real-world scenarios. The creation of metaverse applications is fundamental for the management of emergencies in CIPs. There are several necessary requirements and specifications for the development ofmetaverse applications for emergency management in CIPs.

Requirements for metaverse platform for emergency management in CIPs are as follows:

– System Scalability: The metaverse platform is required to have the capacity to accommodate a large number of users and a wide range of situations. The platform should be capable of processing real-time data from various sources to provide timely and accurate information to all stakeholders such as rescue teams, facility operators and local authorities.

– User-Friendly Interface: The metaverse platform is recommended to have an industry-specific navigation; for example, designing intuitive navigation that reflects the layout and structure of CIPs, enabling users to easily locate key areas, equipment and emergency resources within the virtual environment.. Users in the metaverse platform should be able to navigate through the environment effortlessly and communicate with each other effectively.

– Real-time Data Analysis: The metaverse platform is required to process real-time data and analyse the effects of emergencies such as leaks or fires. The application should provide decision-makers with accurate information, including possible evacuation routes and the impact of the emergency on the environment.

– Security and PII (Personal Identifiable Information) protection: The metaverse platform is required to be designed with security and PII protection in mind. Accessing to the application is recommended to be restricted to authorized personnel, and the data transmitted through the application should be protected from cyberattacks.

8 Application scenarios

Metaverse applications in emergency management refer to a virtual space created by the convergence of physical and virtual worlds, and it allows users to interact with an immersive virtual environment that mimics the real world. In recent years, metaverse applications have emerged as a promising tool for emergency management in high-risk places such as chemical industrial parks.

8.1 Digital twin-based risk perception and decision support

In chemical industrial parks, timely detection and response to chemical incidents pose critical challenges. Integrating real-time monitoring and decision support systems within the metaverse offers a promising solution. [b-Duan] underscores the importance of early detection for mitigating pollution accidents. Furthermore, [b-Shao] highlights the value of predictive analysis and decision support in managing potential risks comprehensively. Leveraging metaverse technology enables seamless implementation of such systems through advanced sensor networks, modelling construction and data analytics. By integrating real-time data from various sensors such as air quality sensors and weather sensors, into the metaverse platform, managers can gain a comprehensive view of the emergency situation. This facilitates making informed decisions regarding evacuation and containment strategies, harnessing the immersive and interactive capabilities of the metaverse beyond what traditional digital twins can offer.

8.1.1 Description

This scenario utilizes metaverse technologies to construct a virtual simulation environment for the CIP. By integrating real-time monitoring data from sensor networks and data acquisition systems, real-time monitoring of environmental parameters within the industrial park is achieved. Based on this, utilizing the metaverse platform to integrate real-time monitoring data and historical data, an intelligent decision support system is constructed to provide emergency management personnel with scientific and rapid decision references. The components in this scenario are as follows:

1. Sensor Networks and Data Acquisition Systems: Real-time monitoring of environmental parameters in industrial parks, such as temperature, pressure, gas concentration, and so on.
2. Data Storage and Processing: The collected data is stored and processed for subsequent analysis and applications.
3. Metaverse Platform: Establishing a virtual simulation environment for the industrial park and integrating real-time monitoring data and historical data to realize the metaverse transformation of the industrial park model.
4. Data Virtualization: Digital twin can virtualize real physical environments into digital spaces.
5. Simulation: Through simulation techniques, various emergency scenarios can be simulated in virtual environments to evaluate the effectiveness of emergency plans more comprehensively. Compared to the conventional IoT formalization, it typically only provides real-time data monitoring, lacking the ability to simulate and predict emergency scenarios.
6. Intelligent Decision Support System: Building an intelligent decision support system by integrating multi-source data and simulation results, providing emergency management personnel with more scientific, rapid and accurate decision references. Compared with

conventional IoT formalization platforms, it not only provides support in data monitoring but also contains the functions of intelligent analysis and decision support for complex scenarios.

The implementation of Intelligent Decision Support within the metaverse offers an approach to address the challenges of timely detection and response to chemical incidents in CIPs. Unlike traditional methods, which often face limitations in data integration and scenario analysis, the metaverse provides a virtual environment where complex scenarios can be simulated and analysed comprehensively.

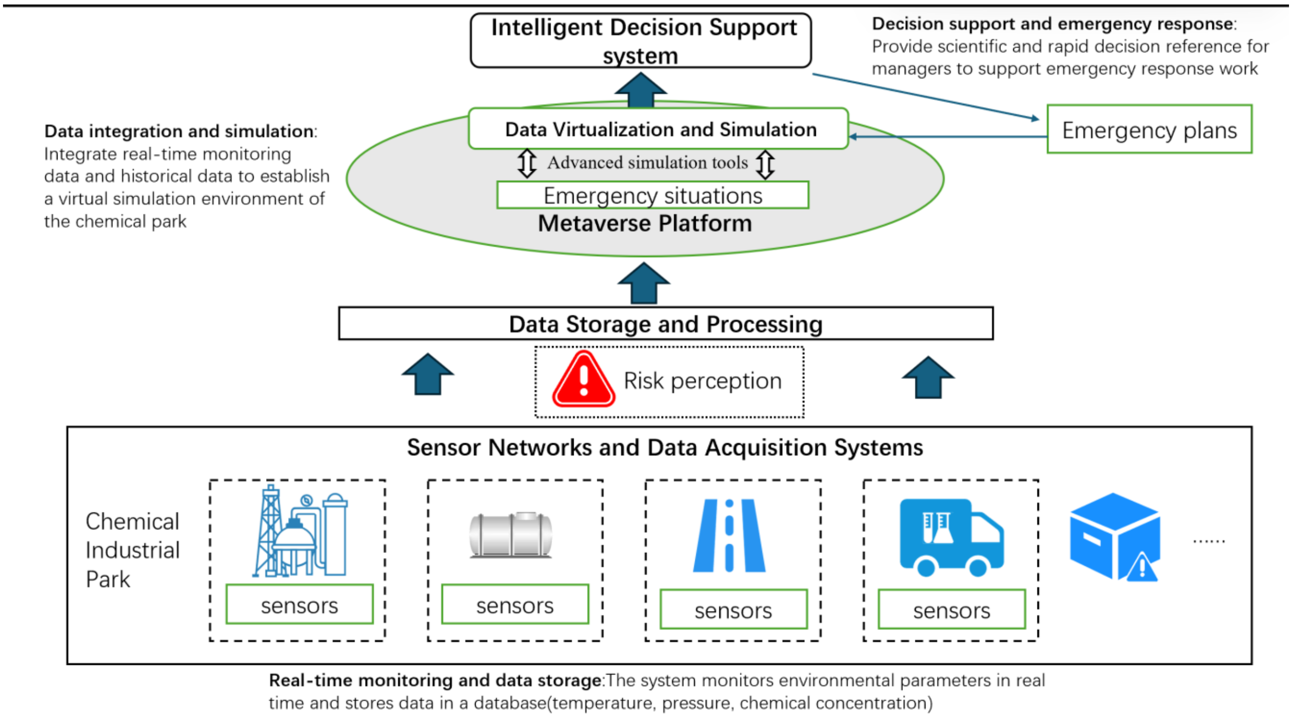

Figure 2: The framework of Risk perception and decision support in metaverse

Figure 1 illustrates the framework of realizing risk perception and decision support in metaverse. The process begins with the real-time data monitoring of parameters in chemical industrial parks through sensor networks and data acquisition systems, facilitating risk perception. This integration allows for the creation of a dynamic and continuously updated representation of the chemical industrial park's environmental conditions. Advanced simulation tools within the metaverse environment enable the modelling of various emergency scenarios such as chemical spills or air pollution events. These simulations take into account factors such as wind patterns, terrain features and chemical dispersion characteristics to predict the spread and impact of incidents accurately.

The metaverse also facilitates the visualization of simulated scenarios in immersive 3D environments, providing emergency managers with a realistic view of potential emergency situations. This immersive visualization enhances situational awareness and enables decision-makers to assess the effectiveness of different response strategies in real time. Furthermore, the metaverse's capability to integrate data from multiple sources and simulate complex scenarios enables the development of an intelligent decision support system. This system analyses real-time data, historical incident data, and simulation results to provide emergency management personnel with scientifically informed decision-making guidance.

In conclusion, the integration of risk perception and decision support within the metaverse empowers emergency managers with advanced tools for proactive emergency response. By leveraging the metaverse's capabilities for data integration, simulation and visualization, emergency management personnel can make more informed decisions, leading to improved outcomes during environmental incidents in chemical industrial parks.

8.1.2 Assumptions

The assumptions related to this scenario include the following;

– It is assumed that the data collected from sensor networks and data acquisition systems within the metaverse platform are accurate and reliable.

– It is assumed that the simulation tools within the metaverse environment accurately model various emergency scenarios.

– It is assumed that the metaverse platform operates efficiently and effectively in transforming the chemical industrial park model and facilitating risk perception.

8.1.3 Service scenario

This Figure 2 describes the service flow for the scenario.

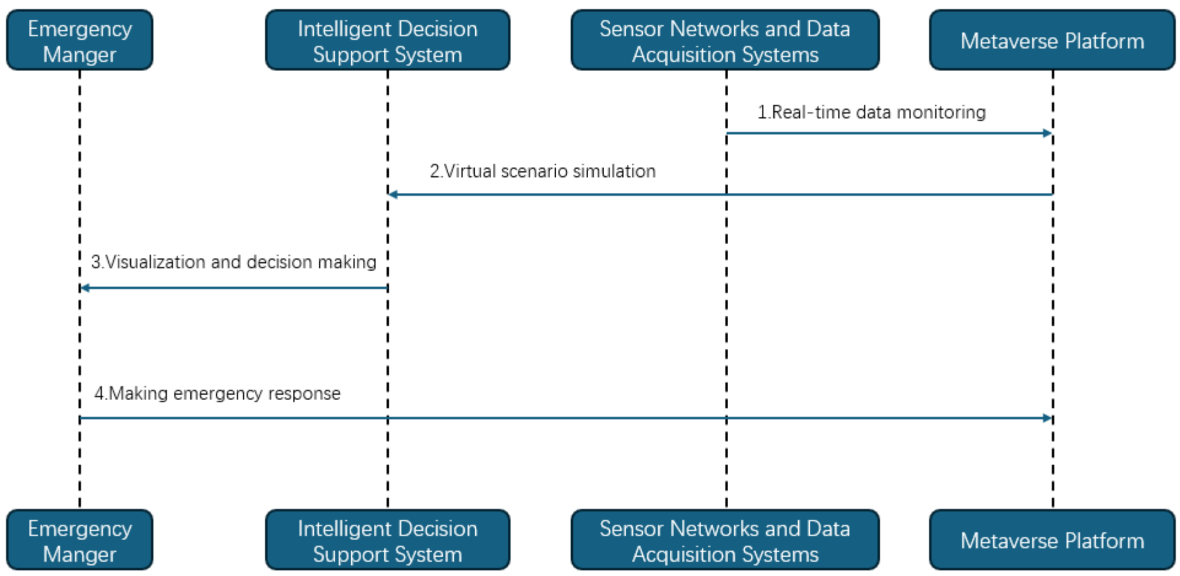

Figure 3: Service flows for Risk perception and decision support in metaverse

1. Sensor networks and data acquisition systems, following rigorous quality assurance protocols and expert verification, monitor environmental parameters within the chemical industrial park. Subsequently, verified real-time data is transmitted to the metaverse platform for further analysis and processing.

2. Various emergency scenarios are simulated using advanced simulation tools within the metaverse, coordinated by the manager, considering factors such as wind patterns and chemical dispersion characteristics.

3. The manager through the intelligent decision support systems analyses real-time data, historical incident data, and simulation results for emergency mangers.

4. Emergency mangers make informed decisions, leading to improved outcomes during environmental incidents in chemical industrial parks.

8.2 Virtual training for emergency drill in metaverse

Emergency drills are a crucial part of chemical park management. These exercises are designed to train employees on how to respond in emergencies, in order to minimize casualties and property damage. Emergency drills include procedures for dealing with fires, leaks and explosions. It is important to carry out emergency drills in emergency management because there are many dangerous chemical production equipment and storage devices in the chemical industrial park. Moreover it is also an effective way to test an emergency plan. [b-Feng].

Metaverse can provide realistic training scenarios for emergency responders by simulating chemical accidents. They enable responders to practice respondse to chemical accidents in a virtual environment, ultimately enhancing their response skills and effectiveness.

8.2.1 Description

VR simulation technology offers effective training opportunities due to its inherent features of reproducibility, just-in-time training, and repeatability. It enables employees to practice safety procedures and respond to emergency scenarios in a controlled, virtual environment.

In this application scenario, the target is to achieve immersive emergency drills in virtual environments to enhance employees' skills and preparedness. The procedures for virtual training in metaverse platforms are as follows:

1. Strategy Development: This step involves identifying the training programme's needs and setting goals such as improving emergency drill outcomes, mitigating hazards in employee training, and reducing the high costs associated with planning and executing training sessions.
2. Model construction: Mapping out the ideal user journey involves pinpointing 3D content, videos, and images to create an immersive training experience. The platform supports the customization and upload of various elements such as vehicles, patrol personnel and emergency supplies to enhance realism.
   NOTE: The platform offers robust features for creating immersive virtual environments. Users can easily draw points, lines, surface vector labels, and graphic labels directly within the VR interface. Additionally, they can plot and customize various elements, including uploading icons, pictures and models such as vehicles, patrol personnel, rescue teams and emergency supplies. Furthermore, the platform supports 720 panoramic views, three-dimensional models, and floor plans, so facilitating seamless navigation and interaction from a macro to a micro level of control within the virtual environment.
3. Content Creation: Utilizing VR technology, the platform combines real-world elements with virtual scenes, enabling enterprises to conduct desktop exercises or command drills. This includes simulating hazardous chemical exposure, fire and explosion hazards, and interactive handling of safety data sheets, which are as follows:

- Hazard chemical exposure: VR training can simulate exposure to hazardous chemicals, allowing employees to experience the effects and understand how to implement proper response procedures. It also helps employees understand how to handle and transport chemicals safely, so reducing the risk of harmful exposure to them.
- Fire and Explosion Hazards: VR training provides hands-on experience in operating heavy machinery, allowing employees understand the risks associated with heavy machinery, understanding associated risks, and developing necessary skills such as the use of fire-prevention tools to prevent accidents.
- Safety training: VR offers a more interactive training experience, allowing workers to practice handling and stirring chemicals in a safe, simulated environment. This ensures better understanding of safety data sheets information and can be used to train workers who may not have easy access to workplace or safety data sheets.

4. Implementation and Roll-out: This step involves deploying the virtual training platform across the organization.
5. Ongoing Support: Continuous improvements to emergency plans are made to ensure effectiveness and relevance over time.

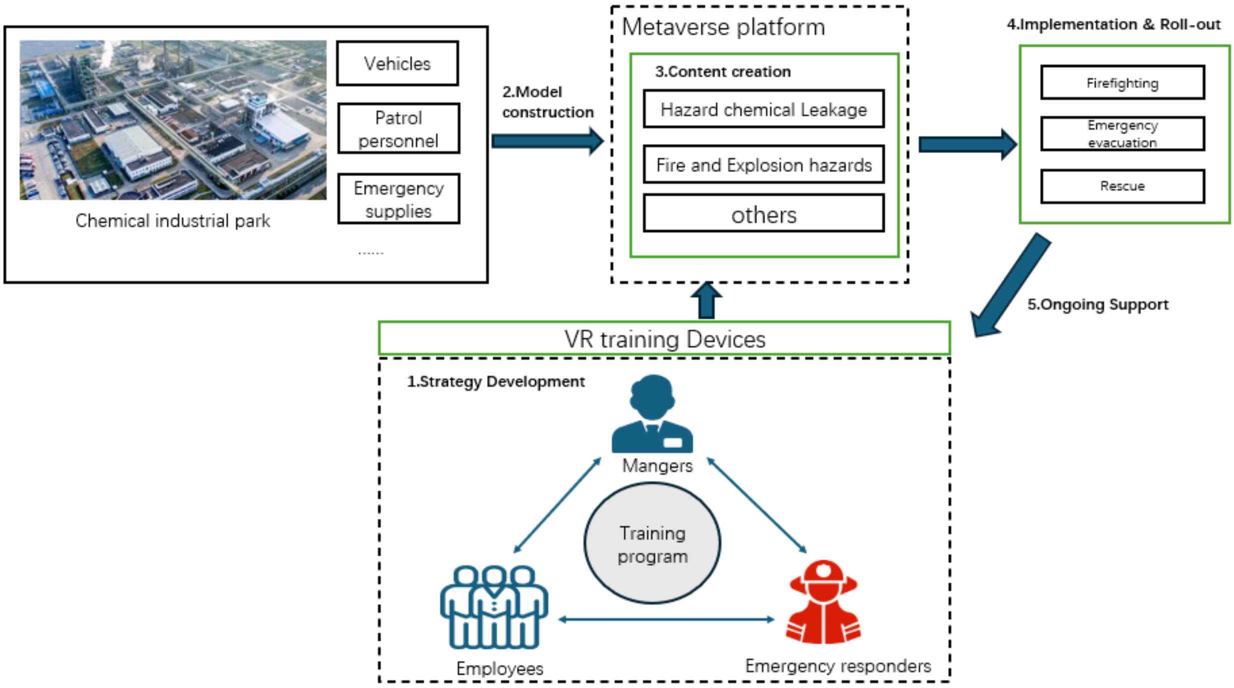

Figure 4: The Steps of realization of virtual training

Figure 3 illustrates the systematic deployment of VR technology for immersive emergency drills within virtual environments. Initially, the process begins with strategic planning and goal setting for the training programme. It aims to identify training needs such as improving emergency response effectiveness and optimizing costs compared to conventional training methods.

Subsequently, the integration of diverse 3D elements, videos, and images is undertaken to craft a realistic and immersive training milieu. The metaverse platform supports customization and the integration of critical elements like vehicles, patrol personnel, and emergency supplies, thus heightening the fidelity of the simulated scenarios. Utilizing VR technology, real-world scenarios are recreated in virtual environments in order to replicate emergency situations accurately. This includes simulating hazardous chemical leakage, fire outbreaks and explosion hazards, and provides safety protocol training, so ensuring comprehensive preparedness and skill development among personnel.

The virtual training platform is deployed across the organization, allowing employees to access to dynamic training modules covering firefighting, emergency evacuation and rescue procedures. Lastly, an iterative process of continuous improvements is instituted to refine the VR training programme and emergency plans to ensure ongoing relevance and effectiveness in mitigating emergent risks within chemical industrial settings.

The integration of VR technology into emergency training presents a sophisticated and interactive approach to foster employee skills and preparedness in addressing diverse emergency scenarios within chemical industrial parks.

8.2.2 Assumptions

The assumptions related to this scenario include the following;

– It is assumed that the rescue teams have access to advanced VR simulation technology capable of creating immersive virtual environments for training purposes.

– It is assumed that the metaverse platform could provide robust features for creating immersive virtual environments, so allowing users to customize various elements and upload content such as 3D models, images and videos to enhance realism.

– It is assumed that the VR training programme integrates real-world elements with virtual scenes to create realistic training scenarios, including simulations of hazardous chemical exposure, fire and explosion hazards, and interactive safety training exercises.

8.2.3 Service scenario

Figure 4 describes the service flow for the scenario.

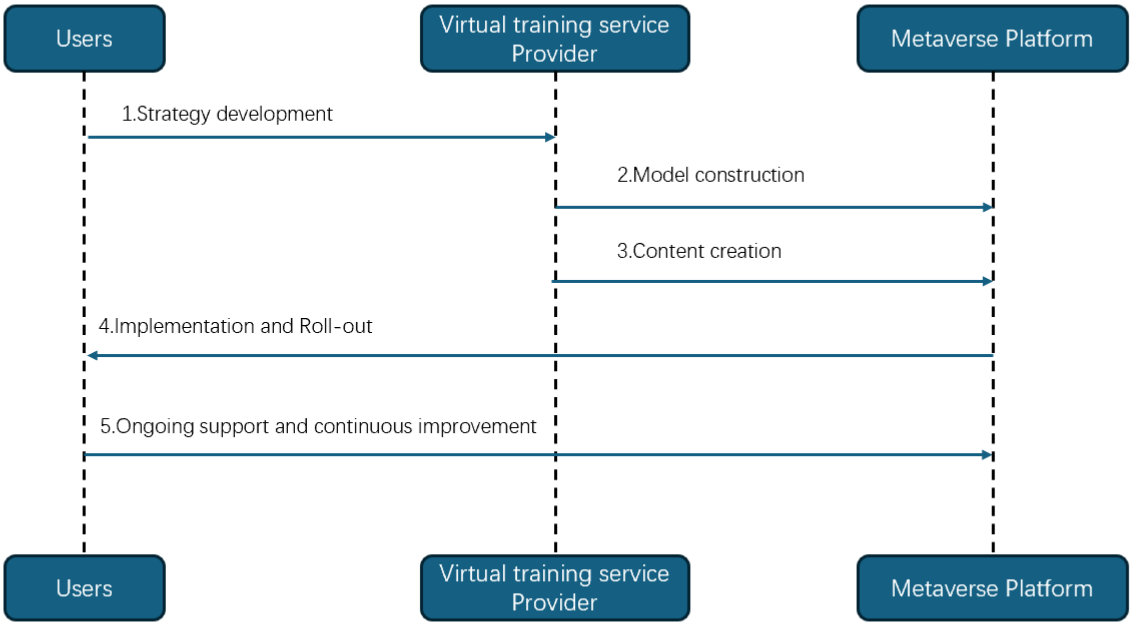

Figure 5: Service flows for virtual training

1. Strategic development is conducted to set clear goals for the VR training programme.

2. Utilizing the metaverse platform's customization features, the users map out the ideal user journey by pinpointing 3D content, videos, and images. Various elements such as vehicles, patrol personnel, and emergency supplies are integrated to enhance realism within the virtual environment.

3. VR technology is utilized to combine real-world elements with virtual scenes, allowing for the creation of immersive emergency training exercises. These exercises include simulations of hazardous chemical exposure, fire and explosion hazards, and interactive safety protocol training.

4. The developed VR training platform is deployed across the users, enabling employees to access dynamic emergency drills covering firefighting, emergency evacuation, and rescue procedures.

5. Through iterative process of continuous improvement, it is to refine the VR training programme and emergency plans over time. Feedback from training sessions and emerging risks within chemical industrial settings are incorporated to ensure the ongoing relevance and effectiveness of the training programme.

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